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Mattaponi River slack water data report : temperature, salinity, dissolved oxygen, 1970 - 1980

T. J. Brooks

Virginia Institute of Marine Science

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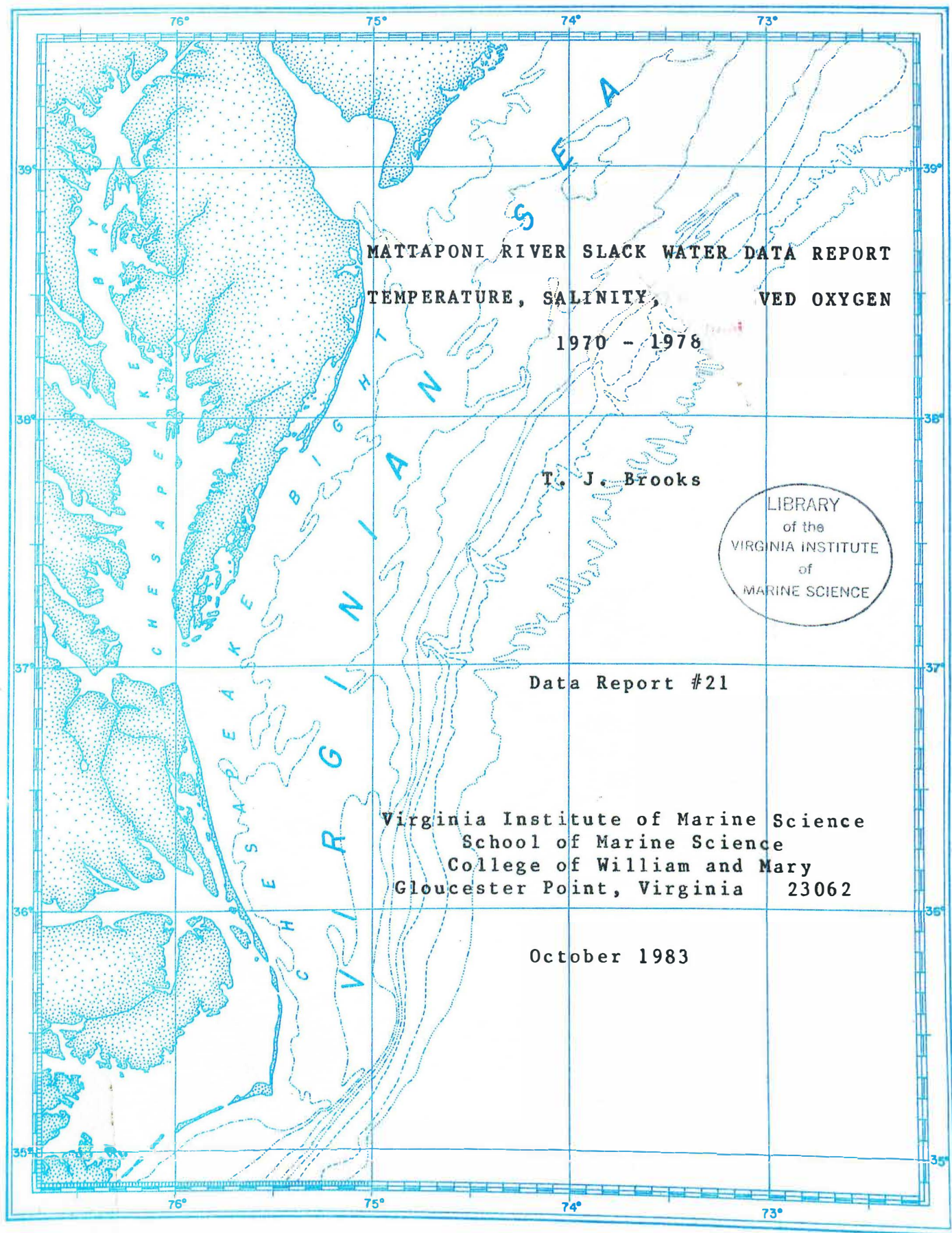
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VIMS
Data Report
No. 21



MATTAPONI RIVER SLACK WATER DATA REPORT
TEMPERATURE, SALINITY, DISSOLVED OXYGEN
1970 - 1978

T. J. Brooks

Data Report #21

Virginia Institute of Marine Science
School of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

October 1983

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Over the past ten years, many students and technicians in the Department of Physical Oceanography and Hydraulics have shared in the hard work and the frustrations that accompany bad weather conditions and the problems of boats and instruments. They also have suggested many improvements based on their accumulated field experience. I particularly thank the following persons for their long time contribution to the program by conducting the field work: Messrs. W. Matthews, S. Snyder, K. Worrell, J. Cumbee and S. Fenstermacher. I also thank Ms. Nancy Courtney for the data reduction and Mr. Hugh Brooks for the development of the interfacing program and the selection of the SURFACE II options.

The funding of this project is jointly provided by the Virginia State Water Control Board and the Virginia Institute of Marine Science through the Cooperative State Agencies program.

INTRODUCTION

The slack water survey program, which has been supported by the State Water Control Board and the Virginia Institute of Marine Science under the Cooperative State Agencies program, provides an extended series of temperature, salinity, dissolved oxygen and nutrient measurements along the Mattaponi River. These have been used to:

- 1) calibrate, verify, and update mathematical models;
- 2) provide a baseline against which effects of unusual events have been measured;

and could be used to:

- 3) establish annual and longer period "climatological" trends in response to changing natural phenomena and man-made modifications to the estuary;
- 4) provide a basis against which fluctuations in biota could be compared.

This report contains station locations, survey schedules, field procedures, sample handling procedures, and data reduction and storage procedures. In addition, 9 years of contoured temperature, salinity, and dissolved oxygen data is presented.

The primary purpose of this report is to provide the data in a format which will be useful to others. Analysis and interpretation of the data is underway and this will be the subject of a later report.

I. SLACK WATER SURVEY PROGRAM

A. Description of the Study Area

The Mattaponi River is located in Virginia as can be seen in Figure 1. The tidal portion of the Mattaponi River extends 66 kilometers from the river mouth in a generally north-west direction (Division of Water Resources, 1970). This portion of the river drains an area of 774 square kilometers and is meandering with extensive marshes. The 71 kilometers of river which are not tidal drain an additional 1604 square kilometers (Seitz, 1971). The average discharge near Beulahville is 17.08 cubic meters per second (cms) based on 39 years of record. The discharge has ranged from 0.17 to 479 cms (USGS, Water Resources Data for Virginia, 1981).

The water surface area of the tidal Mattaponi River is 16.28 square kilometers at mean low water. The mean low water volume is 6.23×10^7 cubic meters. Figure 2 is a plot of the mean tidal range which is 0.94 meters at the mouth and 1.15 meters at a location 53 kilometers further upstream. Figure 3 shows the time difference for high and low water relative to Hampton Roads. The duration of tidal rise and the duration of tidal fall are presented in Figure 4 (Cronin, 1971).

The climate in the study area is classified as humid subtropical. The average annual air temperature in the

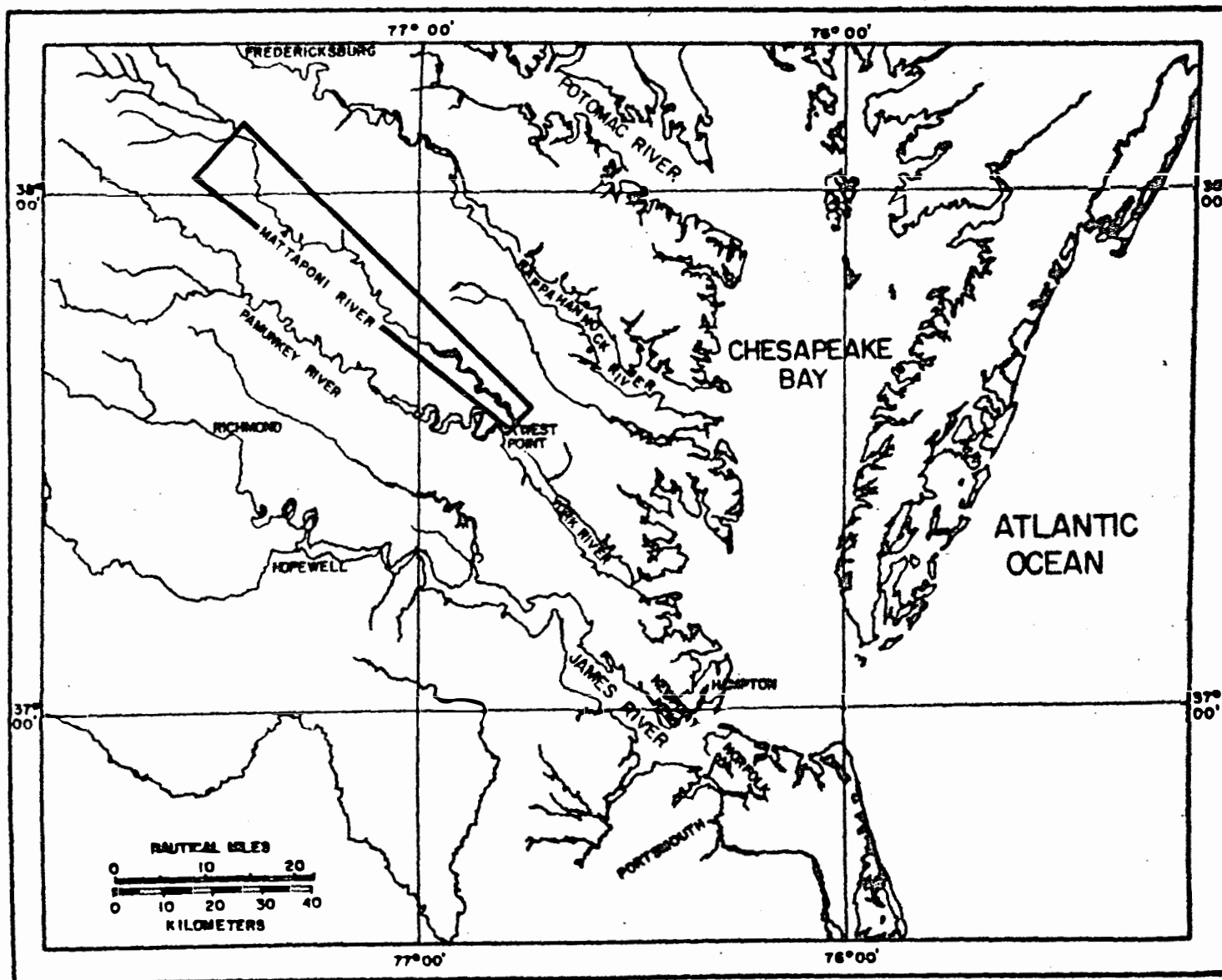


Figure 1. Map Locating the Mattaponi River Within Virginia

Mattaponi River basin is 14.2°C . Average monthly air temperatures range from 3.1°C in January to 25.3°C in July. The average annual precipitation in the basin is 111.5 centimeters (NOAA, Climatological Data, 1980).

B. Slack Water Survey Criteria

A slack water survey is made by taking water samples at designated locations while following either the high or low water slack wave (slack water before ebb tide or slack water before flood tide respectively) as it progresses upstream from the estuary mouth. Most stations are located near the middle of the navigation channel. Water samples from at least two points in the water column, one near the surface and one near the bottom, are taken at each station. At stations of sufficient depth additional points in the water column may be sampled. (See section C, "Field Procedures", for more detailed information.) The locations of the most frequently sampled stations are shown in Figure 5, where the station designation refers to the distance from the river mouth in kilometers. Table 1 lists each station by its kilometer designation, latitude and longitude, and water depth.

A reasonable time table for collecting the samples is 15-20 minutes at the first station. This estimate includes the time spent getting the equipment organized and situated in the boat. Stations up river average 5 to 10 minutes each.

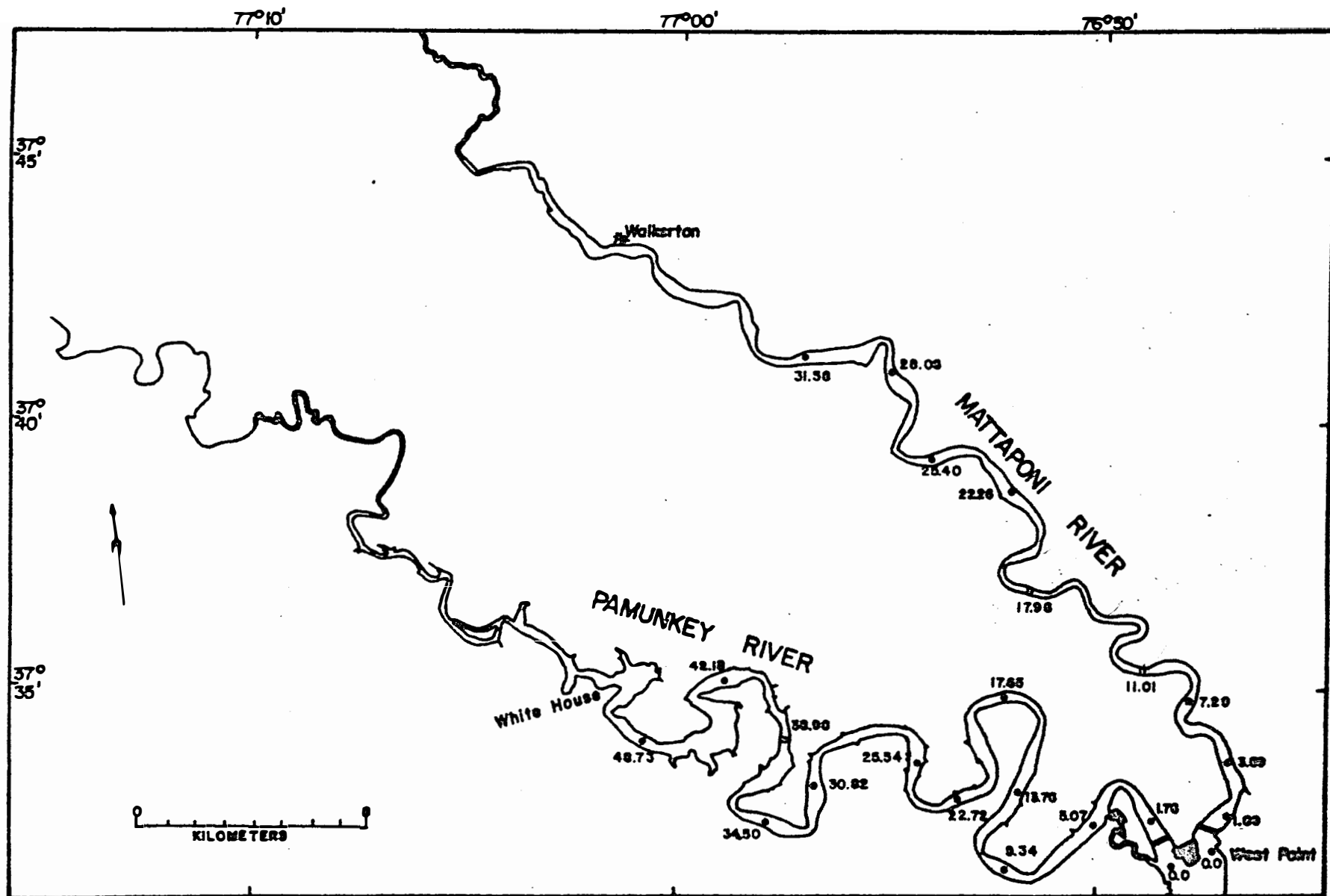


Figure 5. Map of the Mattaponi River Showing the Station Locations

Table 1. Mattaponi River Slack Water Survey Stations

Distance (km)	Latitude (north)	Longitude (west)	Depth (m)
00.00	37-31.7'	76-47.5'	08.7
01.69	37-32.3'	76-47.3'	04.2
03.89	37-33.6'	76-46.8'	04.8
07.29	37-34.7'	76-47.9'	05.7
11.01	37-35.3'	76-49.4'	10.8
17.96	37-36.8'	76-51.4'	10.2
22.26	37-38.4'	76-51.8'	07.2
25.40	37-39.3'	76-53.6'	04.8
28.08	37-41.1'	76-54.9'	05.4
31.58	37-41.2'	76-57.4'	03.9

Every effort is made to complete a slack water survey once it has started. The decision to abort a survey may be made when weather conditions, and more importantly wave conditions, have reached such a point that the slack water time table can not be met. In some cases a few of the stations near the river mouth can be skipped and the survey continued upstream. If half of the river is skipped in order to find more tranquil water conditions the lower portion is rescheduled for no later than the next day. When this is not possible the entire slack water survey is rescheduled.

Surveys usually are conducted monthly, except in the winter, by two-person crews in small outboard boats which are able to keep pace with the slack wave. Winter sampling is generally suspended due to the over-saturation of dissolved oxygen and the low temperatures. The months during which slack water surveys have been conducted are presented in Table 2.

The slack water surveys are scheduled so that the field crews spend the least possible amount of time working during darkness. Usually, the surveys start no earlier than one hour before daylight and are run no later than one hour after sunset. This policy is mainly a safety consideration in an effort to avoid running the boats at top speeds in a limited visibility situation. Since they are the longest, the Rappahannock and James rivers are given first priority as to scheduling dates.

Table 2. Months of Slack Water Surveys
(High and Low) for 1970-1978

Mattaponi River

	1970	1971	1972	1973	1974	1975	1976	1977	1978
	H L	H L	H L	H L	H L	H L	H L	H L	H L
January									
February									
March		(X) X	(X)						
April		(X)	X X	X		(X)	X		
May		X	(X) X	X	(X) (X)	(X)	(X) (X)	(X)	(X)
June		X			(X)		(X)	(X)	(X)
July				(X)	(X) X			(X) (X)	(X)
August	X	X			(X) (X)			(X)	(X)
September		X X	X (X)	(X)	(X)		(X) (X)	(X) (X)	(X)
October	(X)	(X)	(X) (X)	(X)	(X)	(X)		(X)	(X)
November	(X)	(X)	(X)		(X)	X			
December		(X)			(X)				

X : Temperature, Salinity, D.O.

H: High water slack; slack before ebb

(X): T, S, D.O., B.O.D.

L: Low water slack; slack before flood

(X): T, S, D.O., B.O.D., Chlorophyll
and Nutrients

Prior to 1978 when daily precipitation was greater than 0.3 of an inch the survey was postponed for a period of usually three days. This sometimes caused problems as far as scheduling the surveys, especially when the month was drawing to a close. Since 1978 the policy has been changed and the surveys are no longer postponed due to rain.

Figures 6a-i show daily fresh water discharge and the dates of each slack water survey. The fresh water discharge is measured near Beulahville (USGS, Water Resources Data for Virginia, Water Years 1970-1979) and represents approximately 67% of the drainage area of the Mattaponi River basin (Seitz, 1971). Figures 7a-i show average predicted tide heights and the dates of each slack water survey. The tidal data is from Sewells Point and is presented as the average of the high tide heights for each day and the average of the low tide heights for each day (NOAA, Tide Tables 1971-1978).

C. Field Procedures

Several types of samples are collected during each survey. Temperature readings, salinity, and dissolved oxygen samples are taken during each slack water survey. Conductivity readings and biochemical oxygen demand samples are often taken. Since 1974, nutrient concentrations and chlorophyll 'a' have been measured at least a few times each year, as indicated in Table 2.

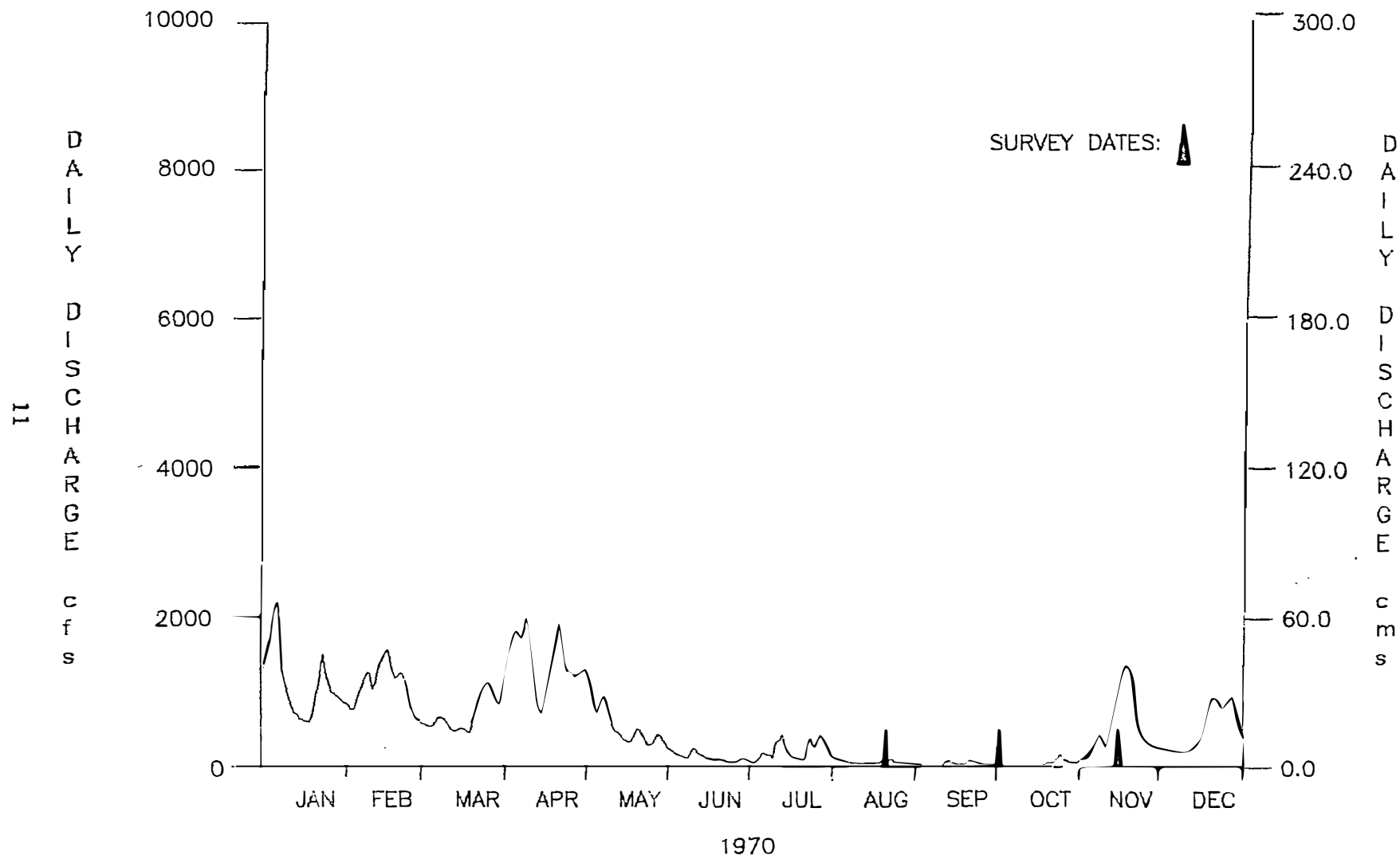


Figure 6a. Fresh Water Discharge and Slack Water Survey Dates, 1970

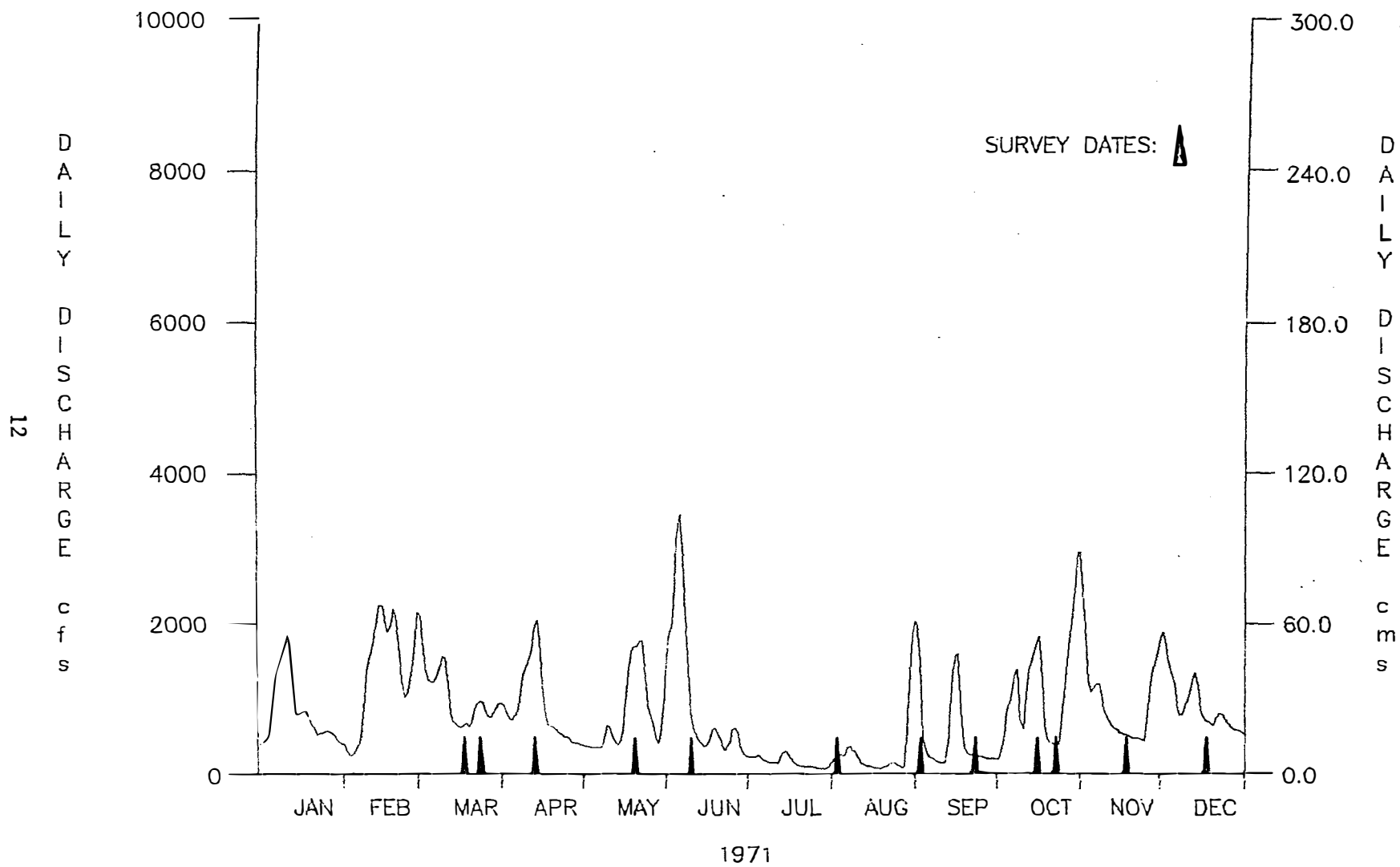


Figure 6b. Fresh Water Discharge and Slack Water Survey Dates, 1971

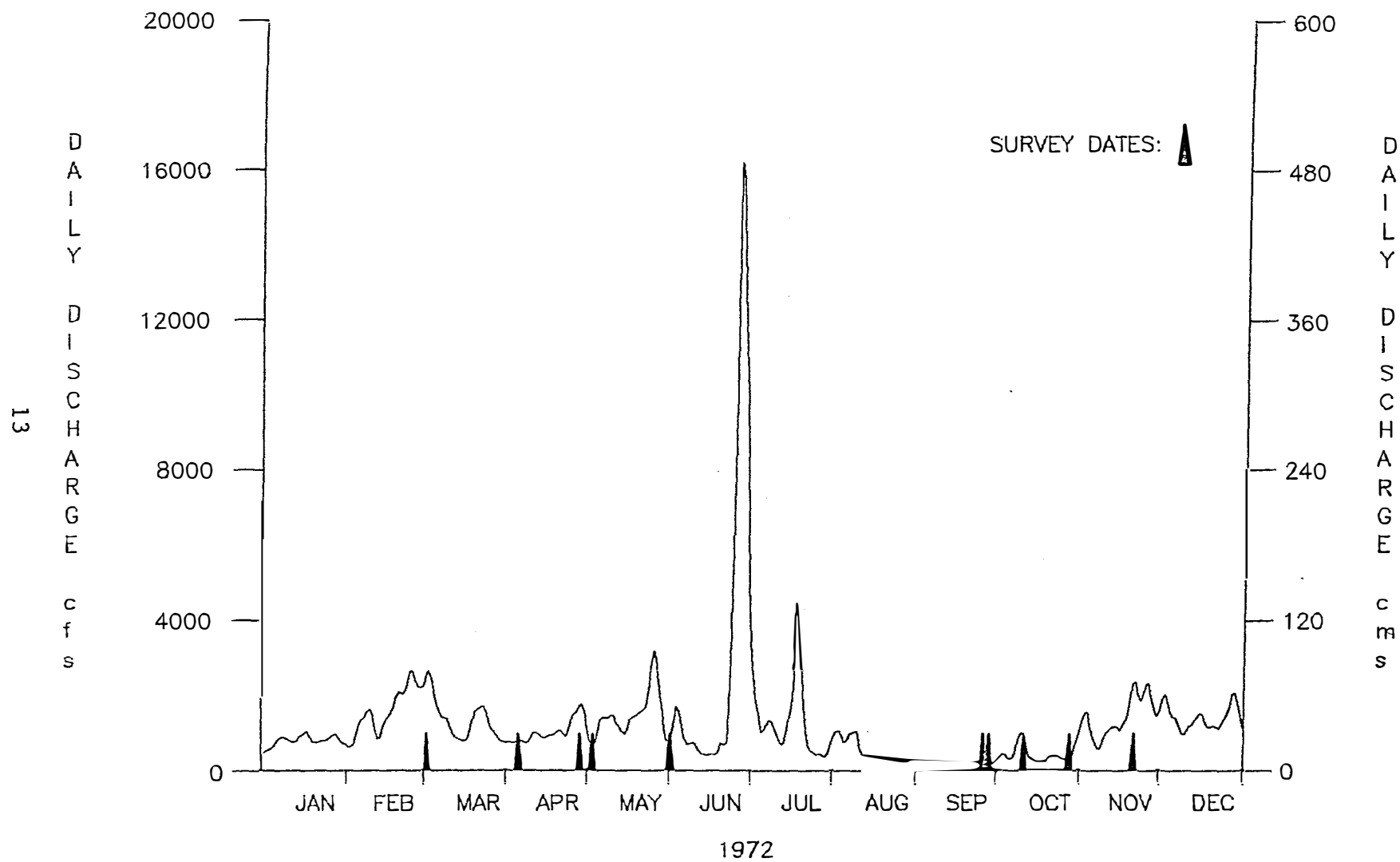


Figure 6c. Fresh Water Discharge and Slack Water Survey Dates, 1972

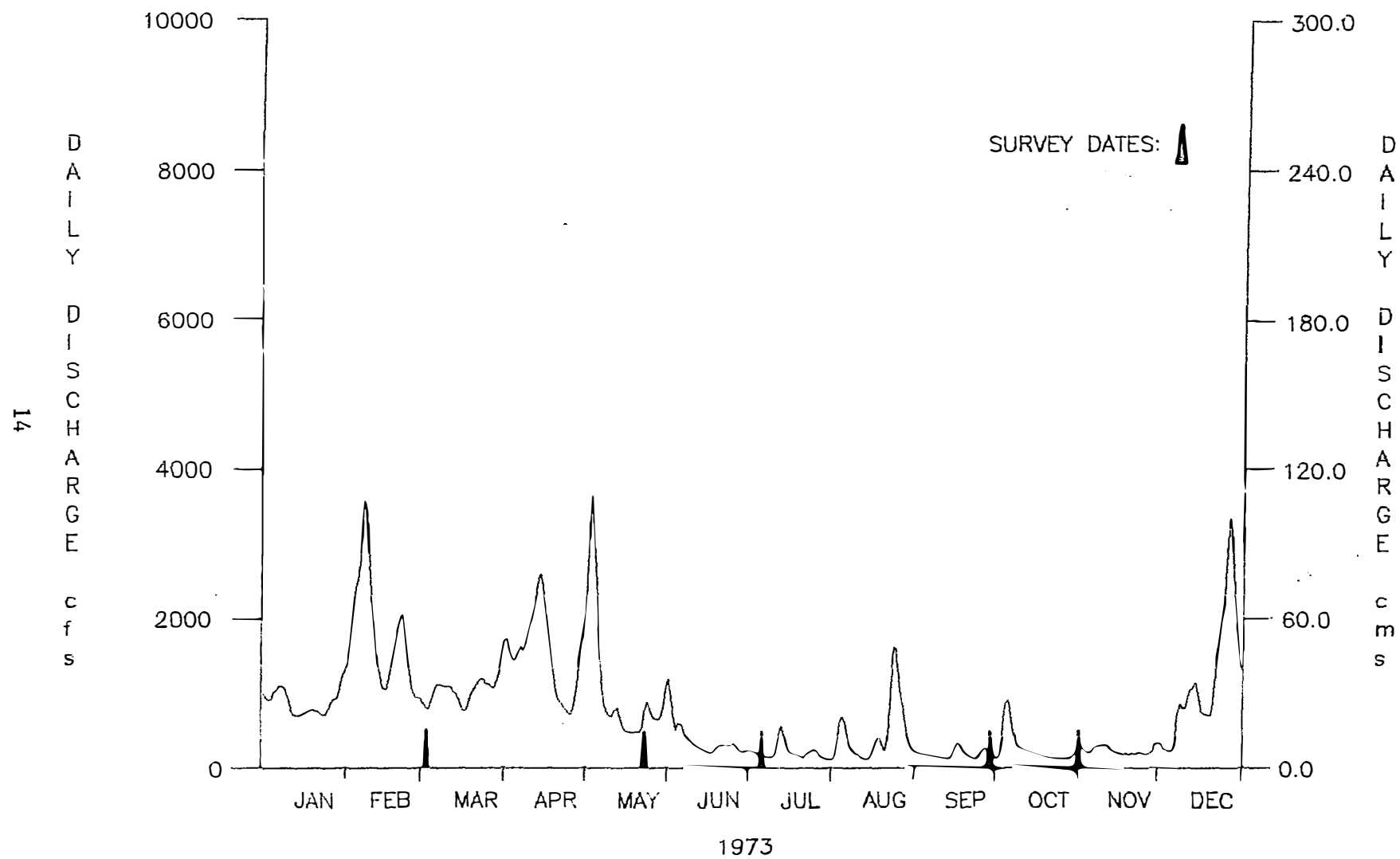


Figure 6d. Fresh Water Discharge and Slack Water Survey Dates, 1973

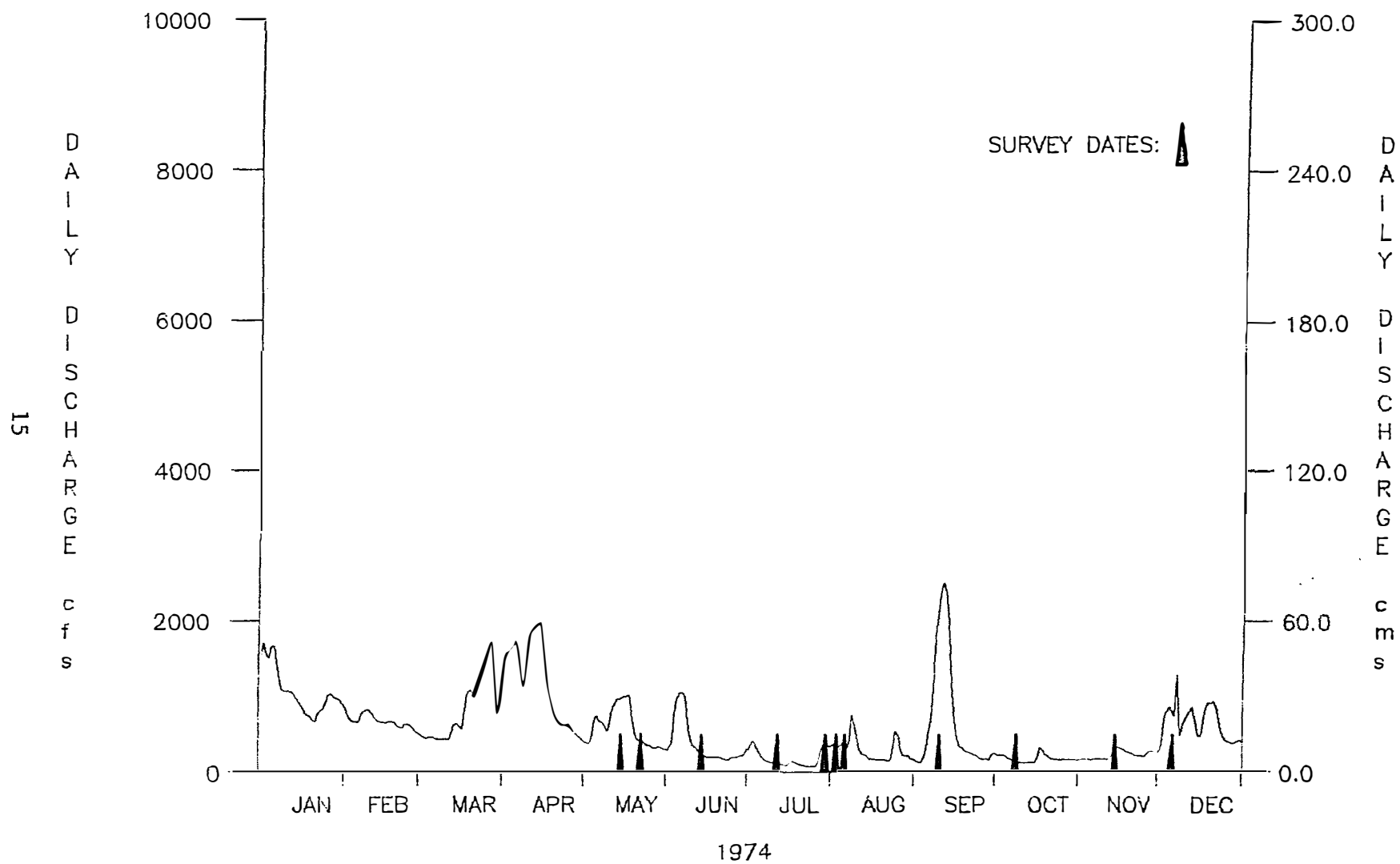


Figure 6e. Fresh Water Discharge and Slack Water Survey Dates, 1974

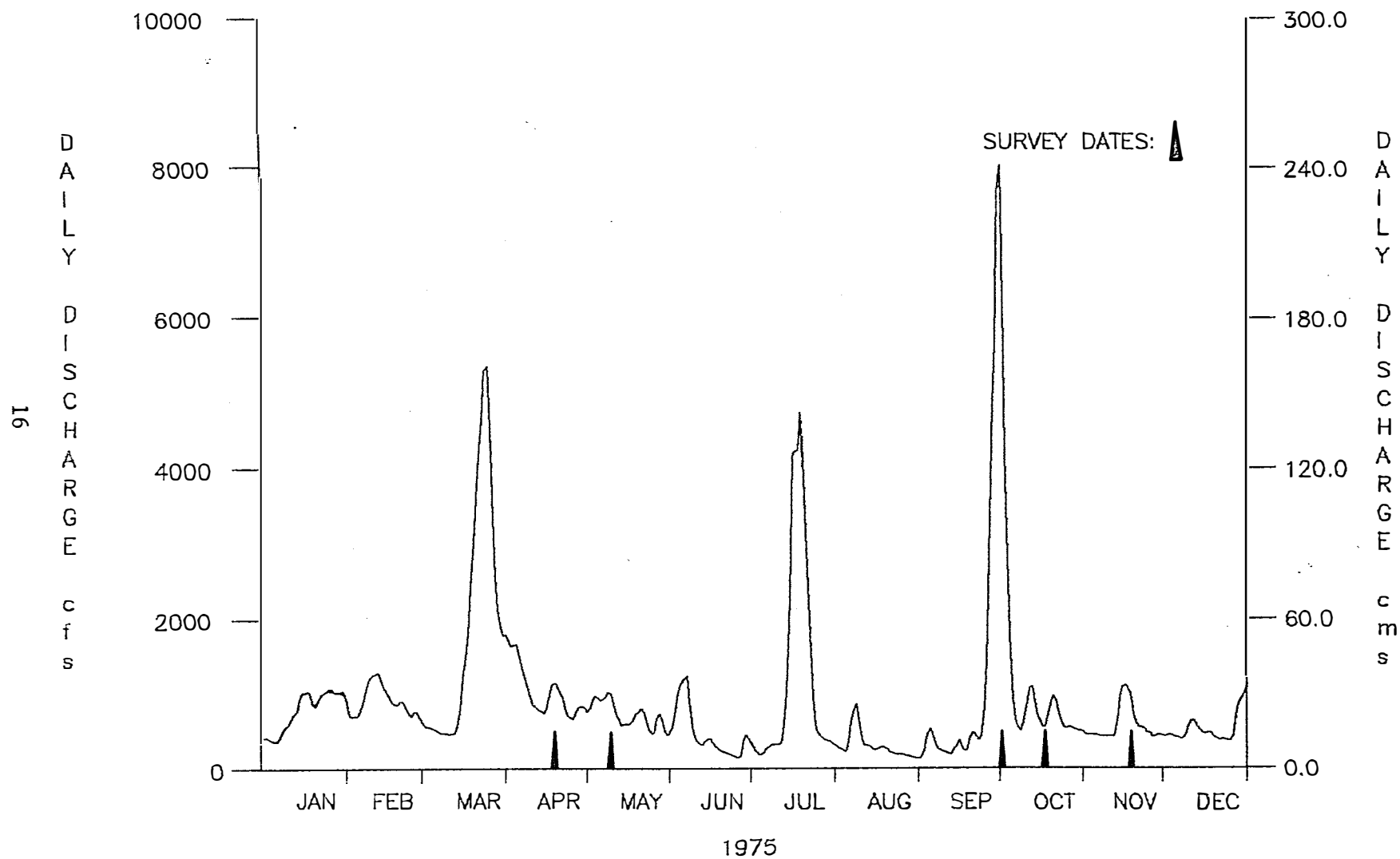


Figure 6f. Fresh Water Discharge and Slack Water Survey Dates, 1975

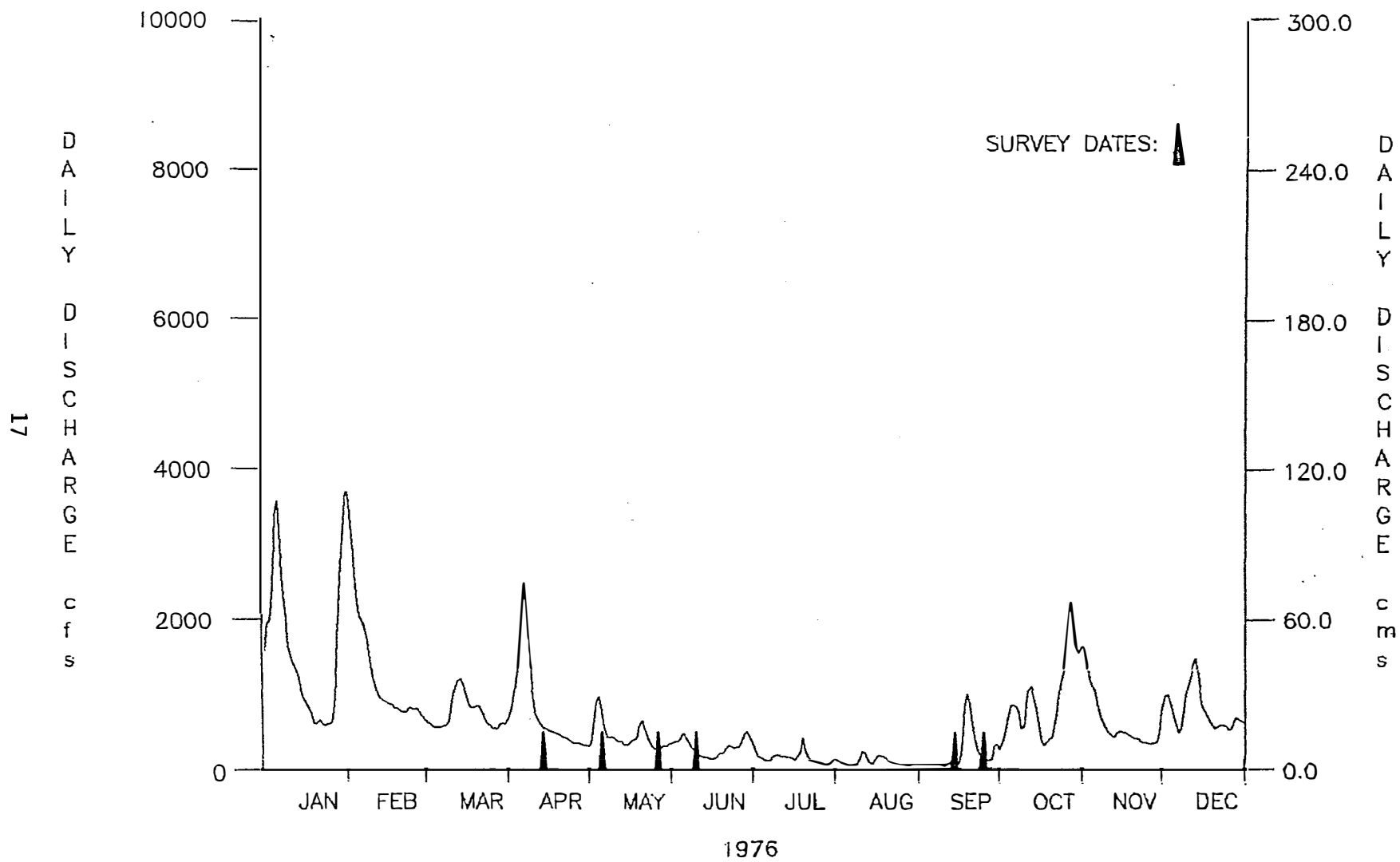


Figure 6g. Fresh Water Discharge and Slack Water Survey Dates, 1976

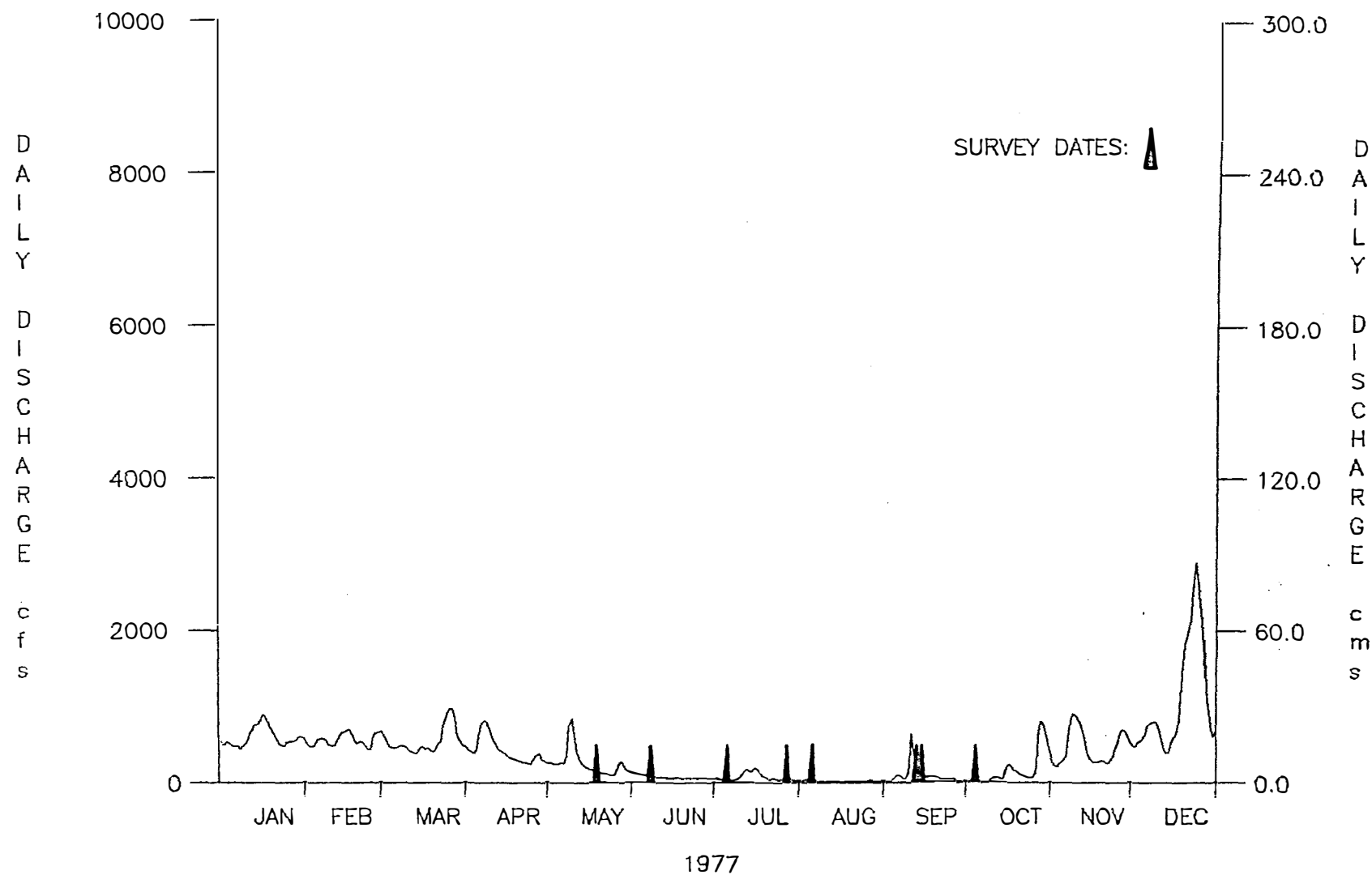


Figure 6h. Fresh Water Discharge and Slack Water Survey Dates, 1977

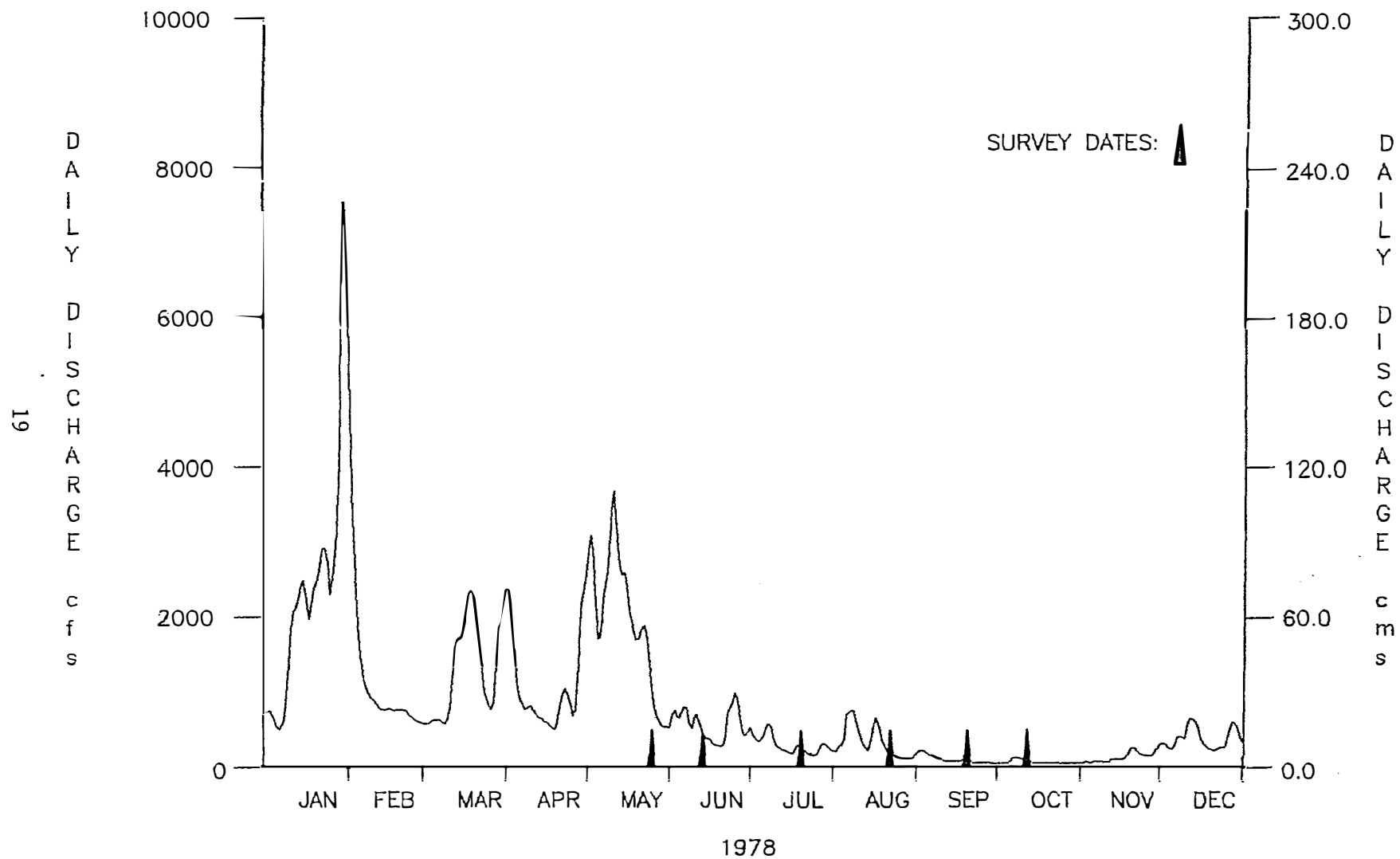


Figure 6i. Fresh Water Discharge and Slack Water Survey Dates, 1978

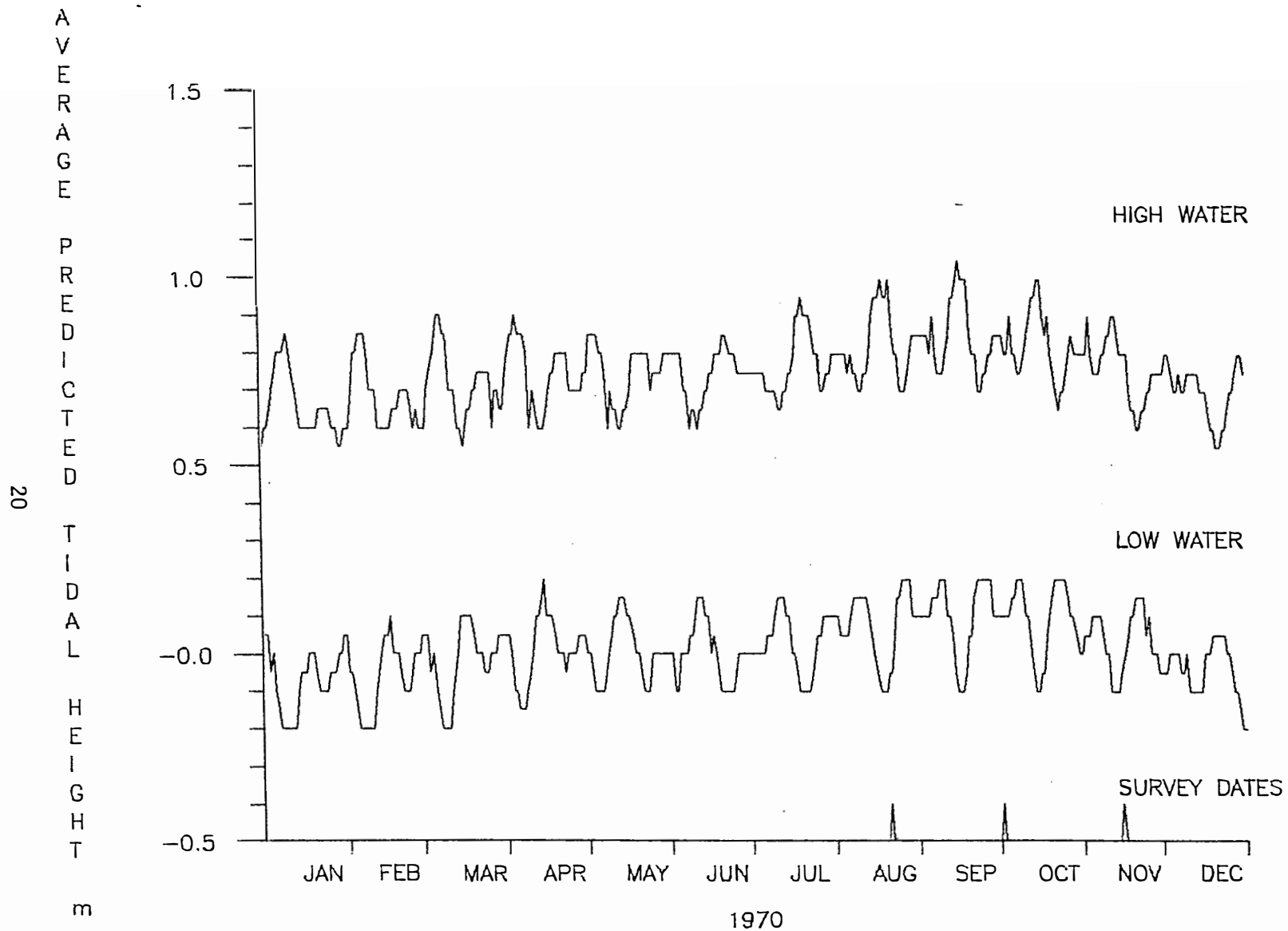


Figure 7a. Average Predicted Tide and Slack Water Survey Dates, 1970

21
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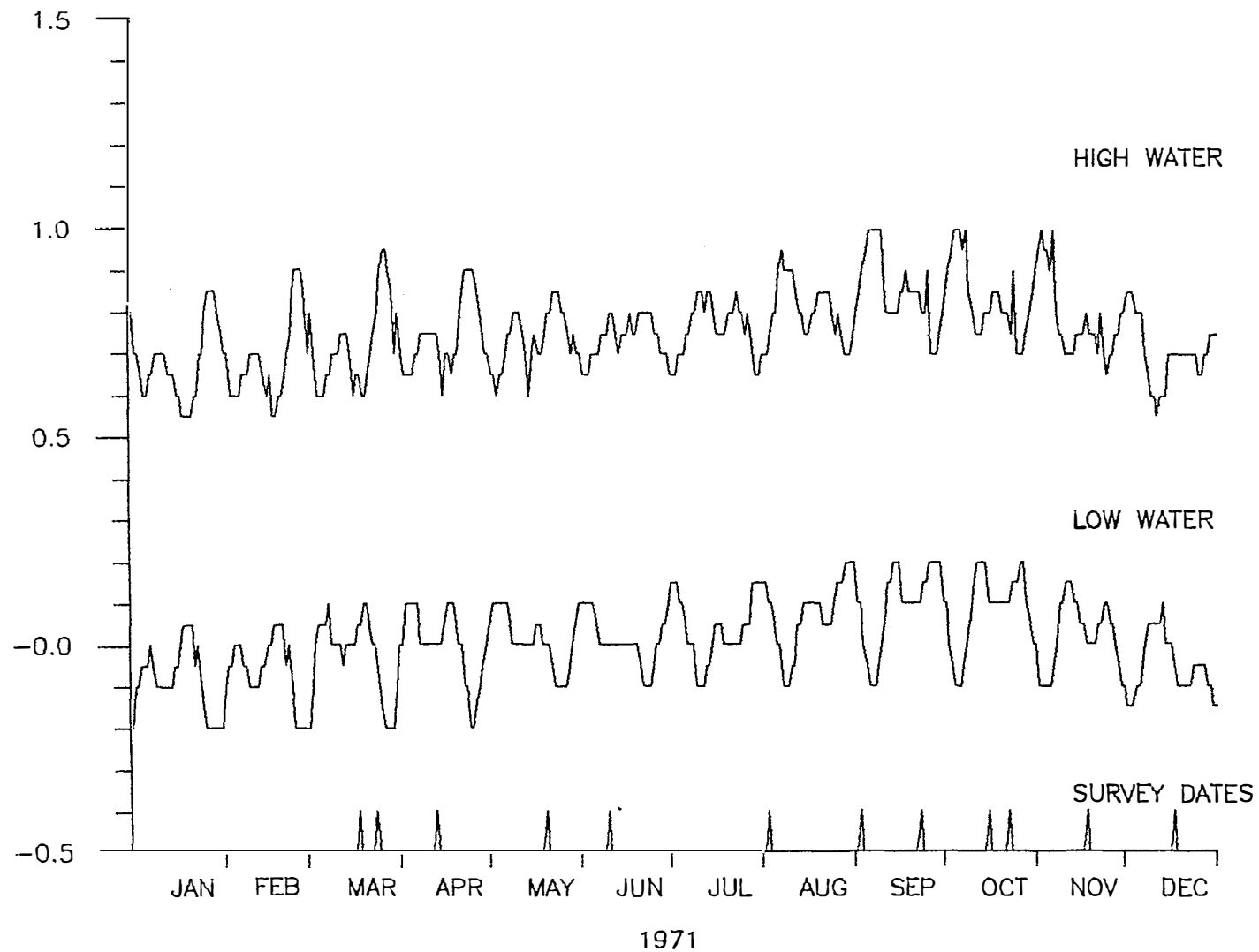


Figure 7b. Average Predicted Tide and Slack Water Survey Dates, 1971

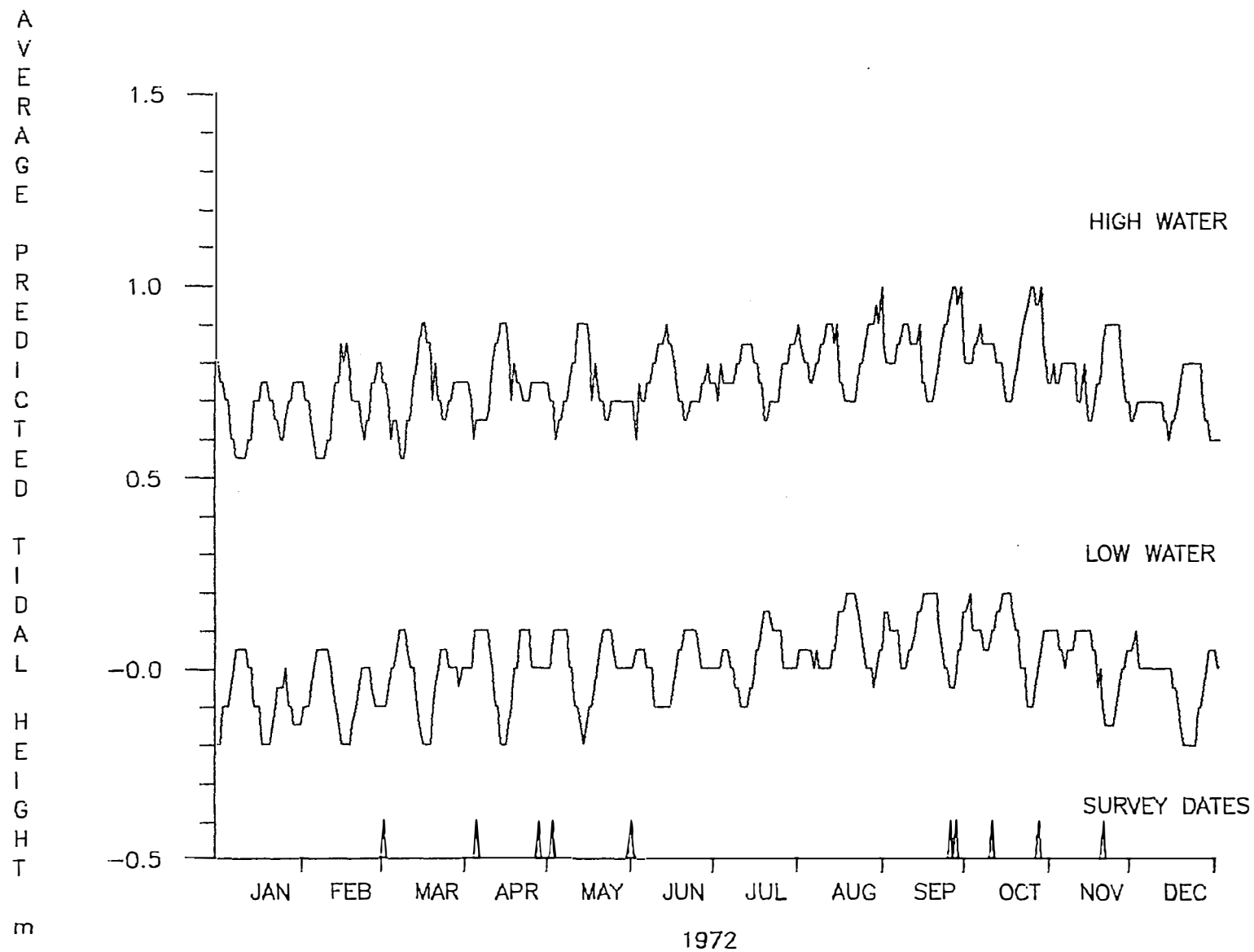


Figure 7c. Average Predicted Tide and Slack Water Survey Dates, 1972

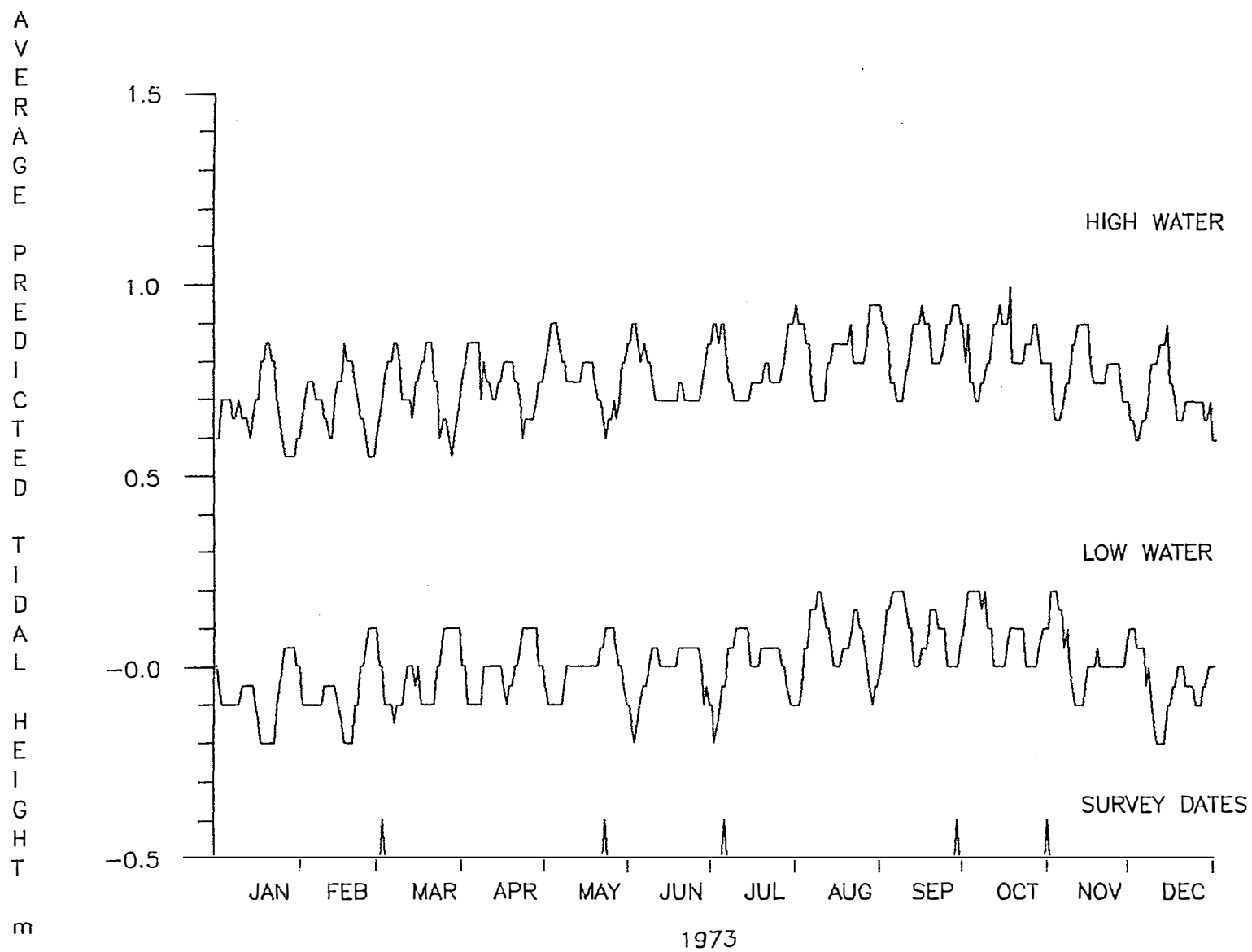


Figure 7d. Average Predicted Tide and Slack Water Survey Dates, 1973

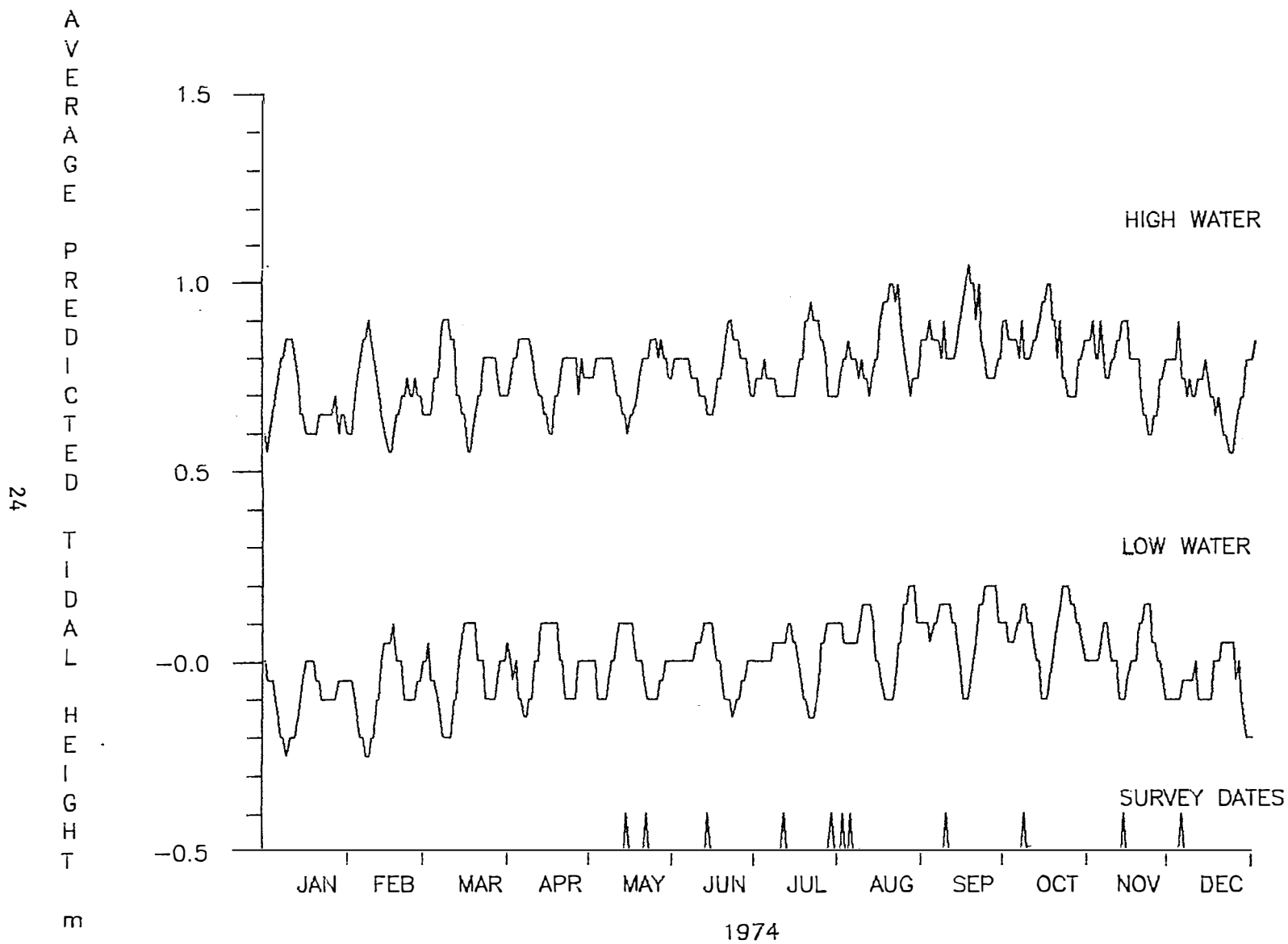


Figure 7e. Average Predicted Tide and Slack Water Survey Dates, 1974

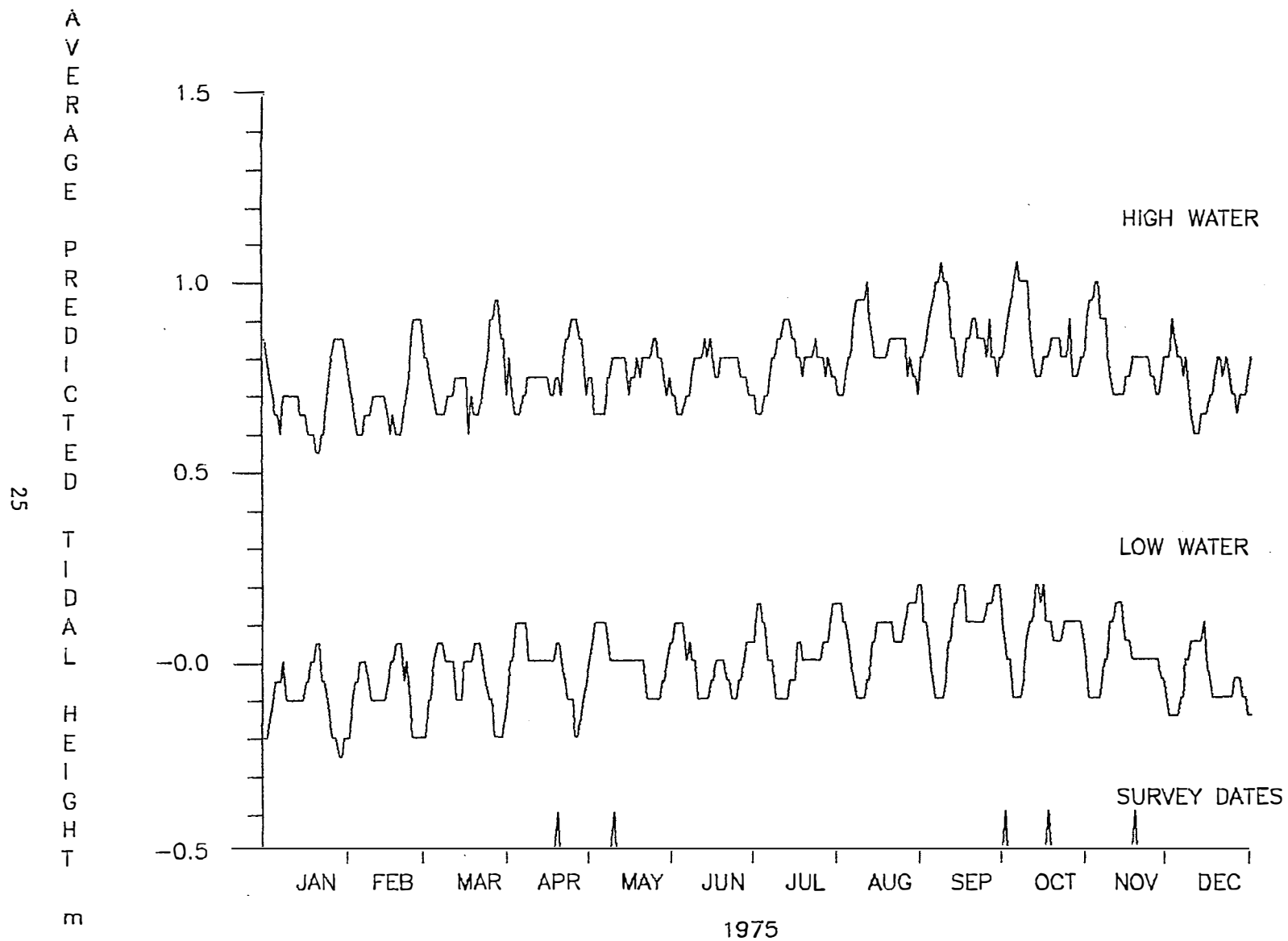


Figure 7f. Average Predicted Tide and Slack Water Survey Dates, 1975

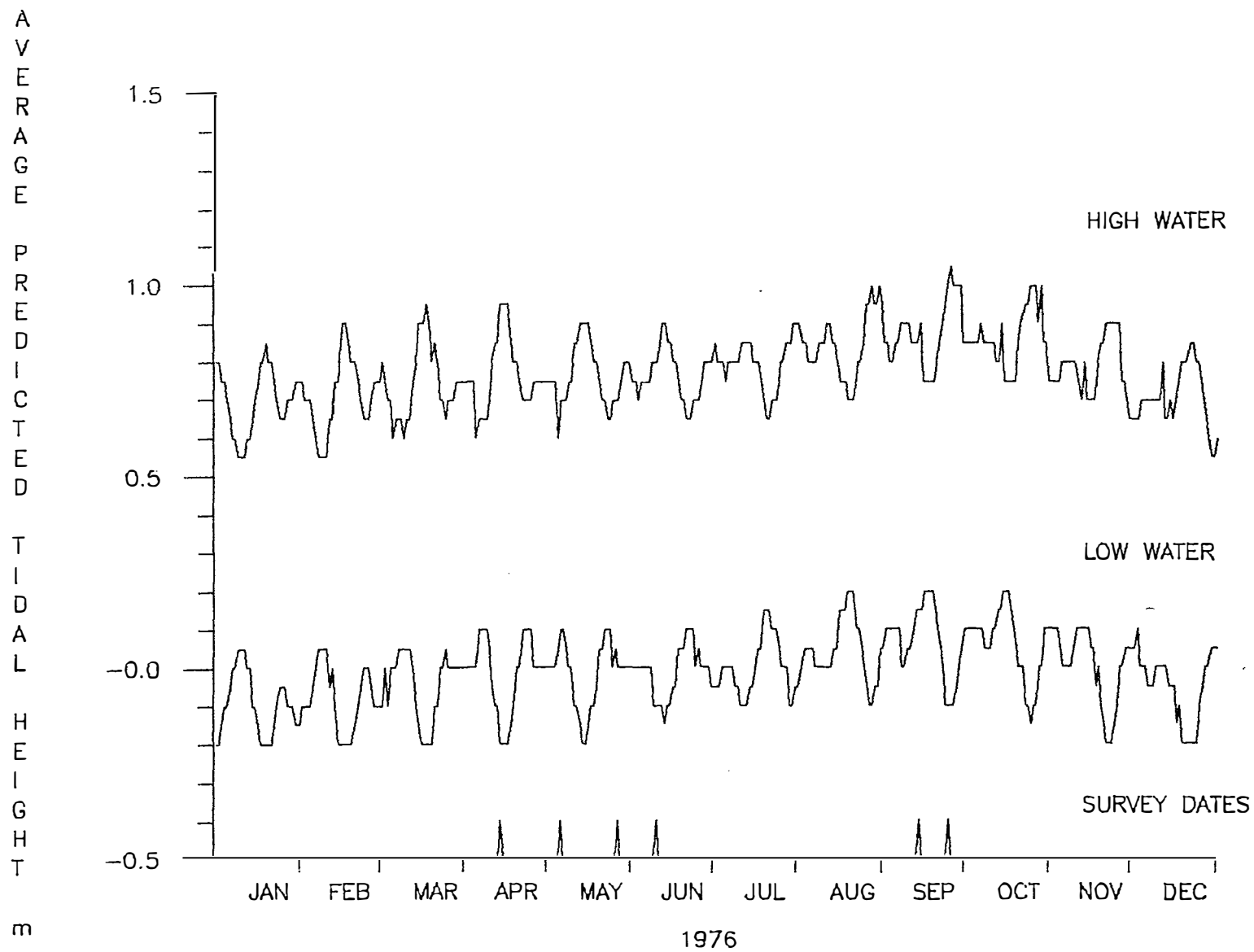


Figure 7g. Average Predicted Tide and Slack Water Survey Dates, 1976

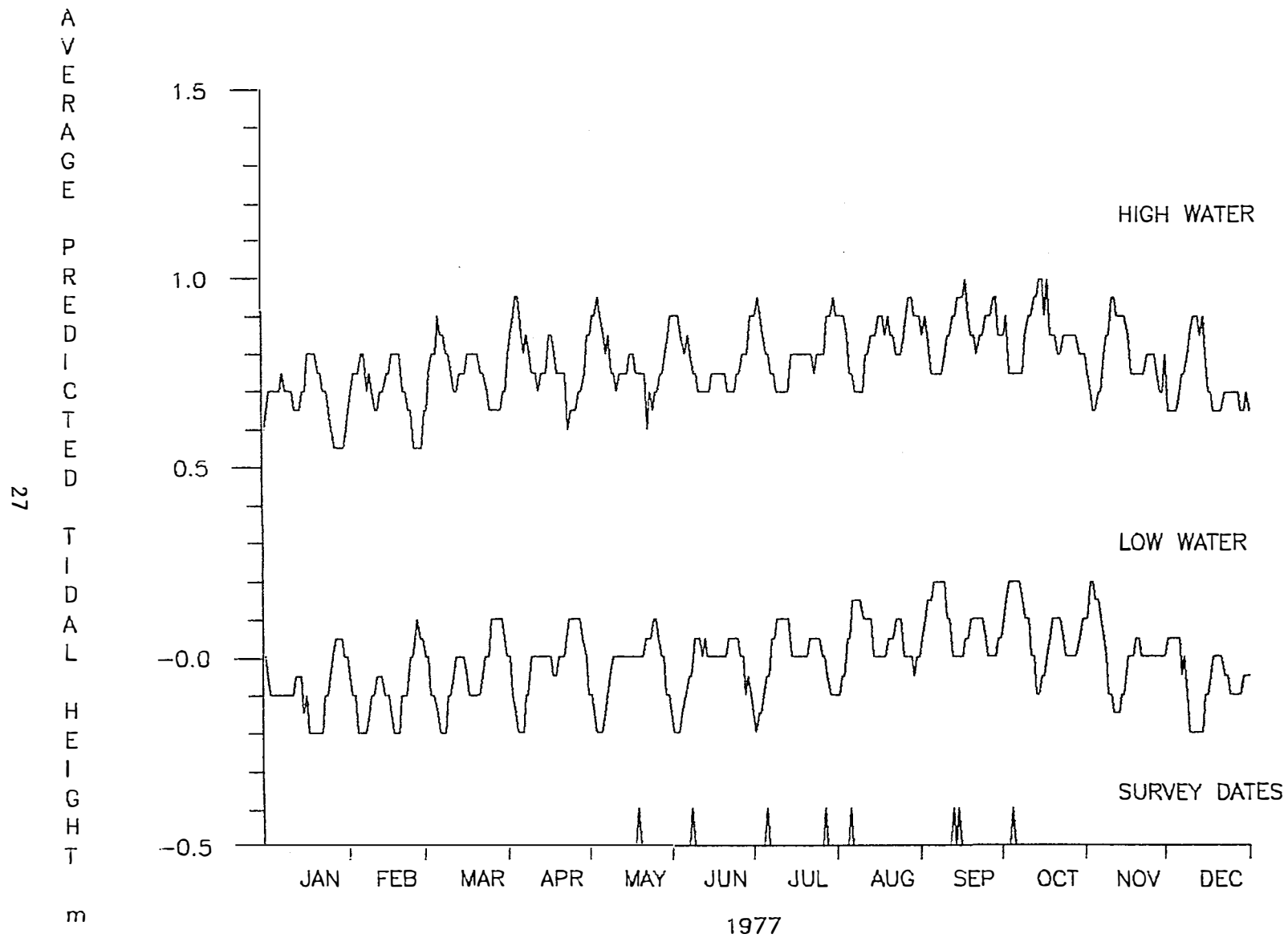


Figure 7h. Average Predicted Tide and Slack Water Survey Dates, 1977

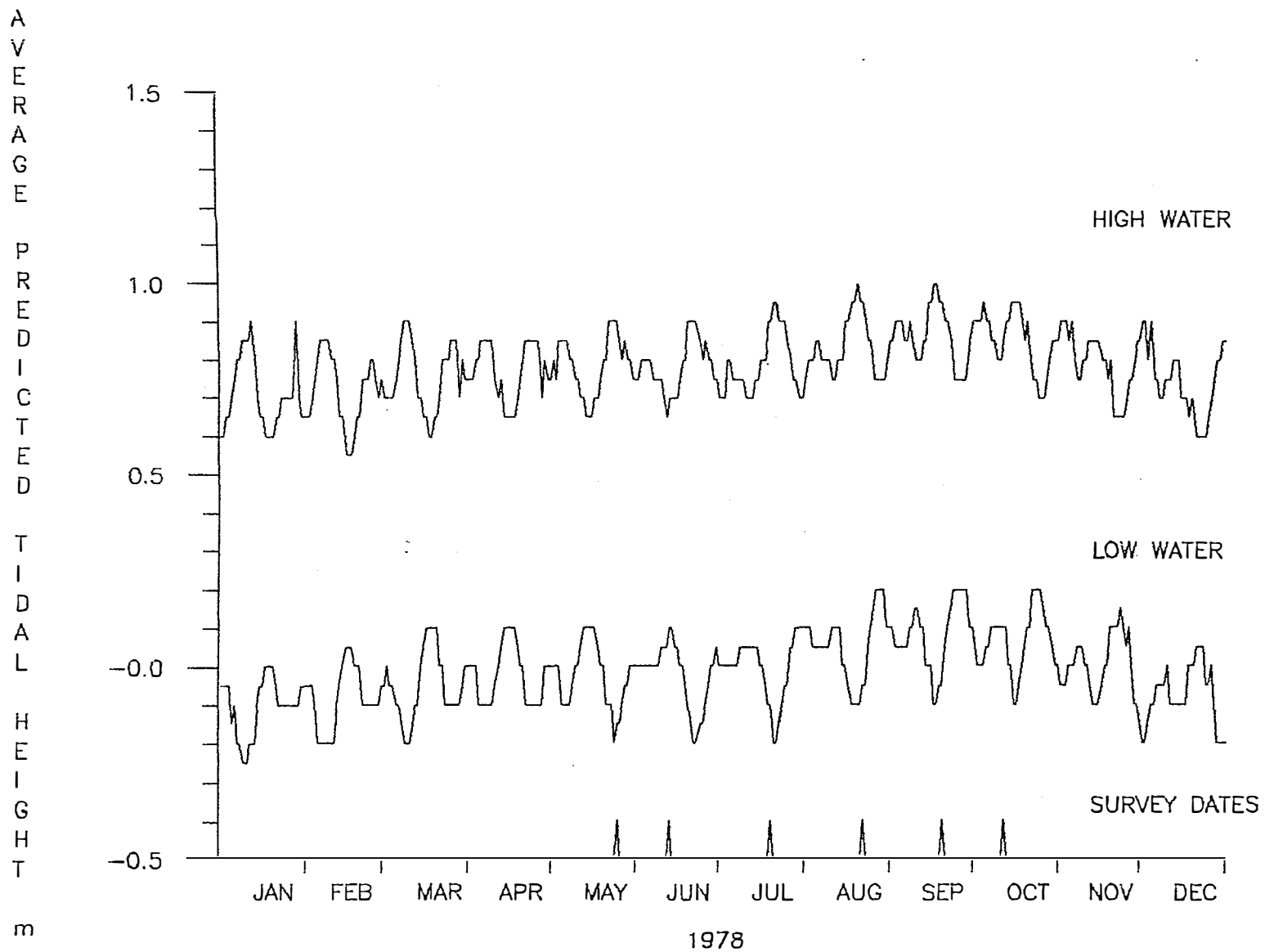


Figure 7i. Average Predicted Tide and Slack Water Survey Dates, 1978

Sampling depths vary with the parameter being considered. Temperature, conductivity, and salinity are sampled every two meters between the surface and the bottom. Dissolved oxygen samples are collected at the surface, mid-depth, and bottom. Biochemical oxygen demand, nutrients, and chlorophyll 'a' samples are collected at the surface and bottom.

Temperature measurements are made with either an Interocean Model 513 CTD instrument or a Hydrolab Model ARA ET-100 thermistor. Conductivity measurements are made with a modified Interocean Model 513 CTD instrument. Water samples for the other analyses are collected by pumping water with a modified bilge pump from the desired sampling depth or with a weighted 5-liter PVC Frautschy bottle attached to a metered line. The bottle is lowered by the hand line to the desired sampling depth, then closed by a messenger and pulled to the surface. At the surface, the water is placed in appropriate containers for various laboratory analyses. While in the field, the instrument readings and sample bottle numbers are recorded on an Oceanography Form 1 as illustrated in Figure 8.

D. Sample Handling Procedures

Samples for salinity are placed in 125-ml sample-rinsed glass bottles. When brought back to the laboratory the samples are run on an Industrial Instrument Laboratory Salinometer Model RS7A. Salinity is sometimes calculated

from temperature and conductivity readings taken from the Interocean Model 513 CTD instrument.

Samples for dissolved oxygen analysis are placed in 125-ml sample-rinsed glass bottles. Reagents are added immediately in preparation for the azide modification of the Winkler procedure to be conducted later in the laboratory.

Biochemical oxygen demand (BOD) samples are collected in standard 300-ml glass stoppered BOD bottles. Nutrient samples are collected in 1-liter plastic "cubitainers". Chlorophyll samples are collected in opaque plastic containers. All three types of samples are placed on ice immediately after collection and until they can be processed in the laboratory. Nutrient and chlorophyll samples are filtered within 24 hours of collection. The details of the laboratory procedures and analytical methods can be found in other VIMS reports such as "Water Quality in the York River" (Sturm and Neilson, 1977).

E. Data Reduction and Storage

Central to the reduction of data collected by the Department of Physical Oceanography and Hydraulics is the Oceanography Form 1. The Form 1 serves the dual purpose of providing a sheet for field and laboratory use as well as a form from which oceanographic data may be entered to the computer-based storage system via either punched cards or magnetic tape.

The data are available on request. Printouts of work done by the Department of Physical Oceanography and Environmental Engineering are kept in the department library and in the VIMS library.

II. DISCUSSION

A. River Discharge

Mattaponi River discharge, measured near Beulahville, during the 1970-1978 study period covered a wide range of values. The maximum daily average discharge was 1.62×10^4 cubic feet per second (cfs) (486 cms). This occurred on 25 June 1972 due to the heavy rains of Tropical Storm Agnes. Minimum daily average discharge was 13 cfs (0.39 cms) and occurred on 13 and 14 August and 2 and 3 September 1977. Mean daily freshwater flow near Beulahville, during the study period, averaged 738 cfs (22.14 cms). The greatest total discharge for a given year during the 9 year study was 4.51×10^5 cubic feet (1.35×10^4 cubic meters) in 1972. The year with the least total discharge was 1977 with 1.30×10^5 cubic feet (3.90×10^3 cubic meters).

B. Temperature

Water temperatures in the Mattaponi River showed a seasonal pattern following the air temperature pattern through the year. Temperatures around 7.8°C were observed in March. The water temperatures increased through the spring reaching maximum temperatures around 27.4°C in July. The mean water temperature declined in August and continued to decrease through the fall.

C. Salinity

Salinity in the Mattaponi River decreased from the mouth to the head of the estuary. The salt content of the water tended to increase with depth.

Salt regularly intruded from West Point to the region around kilometer 18. The 1970-1978 slack water data set showed a maximum intrusion of the 1 ppt isohaline beyond kilometer 25. The minimum intrusion of the 1 ppt isohaline was downstream of West Point. This report does not include data from the study of Tropical Storm Agnes. That study reported a minimum intrusion distance around the area of West Point (Andersen, Davis, Lynch, Schubel (ed.), 1973). In addition to longitudinal movements of the salinity intrusion, salinity has also undergone variable degrees of vertical stratification.

D. Dissolved Oxygen

The dissolved oxygen concentration in an estuary is dependent on several physical and biological factors. The solubility of oxygen is influenced by temperature and salinity. Turbulence affects atmospheric reaeration rates. Metabolism and the decomposition of organic material exert demands on the available oxygen.

The dissolved oxygen values in the Mattaponi River showed a seasonal pattern. The highest values, around 9.6 mg/l, were reported in the winter during the time of low temperatures and reduced oxygen demand. The level of dissolved oxygen decreased through the spring reaching average minimum values around 5.4 mg/l in the summer during the season of low fresh water discharge and increased temperatures and salinities.

The State Water Control Board has set the water quality standards for acceptable levels of dissolved oxygen (State Water Control Board, 1980). The minimum allowable oxygen concentration for estuarine waters is 4.0 mg/l. The daily average concentrations should exceed 5.0 mg/l. Although the dissolved oxygen values in the Mattaponi River were generally above these levels, values less than 4.0 mg/l have occurred between June and October. The minimum value recorded was 1.30 mg/l which occurred at kilometer 0 on 22 September 1971.

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APPENDICES

- A. Longitudinal Contours
- B. Temperature ($^{\circ}\text{C}$)
- C. Salinity (ppt)
- D. Dissolved Oxygen (mg/l)

A. LONGITUDINAL CONTOURS

Longitudinal contours of temperature, salinity and dissolved oxygen have been generated for each of the slack water surveys. A listing of these surveys is contained in Table 3. The bottom profile is based on the water depth at mean low water as taken from National Ocean Survey charts at the most frequently sampled slack water stations.

Temperature, salinity, and dissolved oxygen values are recorded at each depth sampled. When the sampling is taken at an angle to the vertical because of bottom currents or sampling is slightly off-station, the sampled bottom depth can be deeper than the bottom profile. In this case, the sampling depths for the entire cast at that station are scaled so the bottom depths correspond to each other. When the bottom depth sampled is shallower than the bottom of the profile, the sample depths are used as recorded.

SURFACE II is a computer software system developed by the Kansas Geological Survey for computer contouring and graphics display. The user is able to specify plotting options by selecting appropriate operation commands. The isotherms, isohalines, and lines of constant dissolved oxygen in this report have been drawn using a SURFACE II plotting package and Tectronix plotter. When a parameter has been measured by more than one method the most complete data set is used.

Table 3. Dates of Slack Water Surveys and Contours Generated
Mattaponi River

DATE D/M/Y	CRUISE	SLACK	TEMPERATURE	SALINITY	DISSOLVED OXYGEN
200870	OSM01	L	T	N	N
011070	OSM02	H	N	N	N
151170	OSM03	H	T	S	N
170371	OSM01	L	T	S	D
230371	OSM02	H	T	S	D
120471	OSM03	H	T	S	D
190571	OSM04	H	T	S	D
090671	OSM05	L	T	S	D
020871	OSM06	H	T	S	D
020971	OSM07	H	T	N	D
220971	OSM08	L	T	S	D
151071	OSM09	L	T	S	D
221071	OSM10	L	T	S	D
171171	OSM11	H	T	S	D
171271	OSM12	H	T	S	D
010372	OSM01	H	T	S	D
040472	OSM02	L	T	S	D
270472	OSM03	H	T	S	D
020572	OSM04	L	T	N	N
310572	OSM05	H	T	N	D
250972	OSM06	H	T	S	D
270972	OSM07	L	T	S	D
101072	OSM08	H	T	S	D
271072	OSM09	L	T	S	D
201172	OSM11	H	T	S	D
020373	OSM01	H	T	S	N
220573	OSM02	L	T	S	D
050773	OSM03	L	T	S	D
280973	OSM04	L	T	S	D
311073	OSM05	L	T	S	D

H: HIGH WATER SLACK,
SLACK BEFORE EBB
T: TEMPERATURE GENERATED
S: SALINITY GENERATED

L: LOW WATER SLACK,
SLACK BEFORE FLOOD
D: DISSOLVED OXYGEN GENERATED
N: NO CONTOUR GENERATED
(NO DATA AVAILABLE OR NOT
ENOUGH TO CONTOUR)

Table 3. (Cont'd)

DATE D/M/Y	CRUISE	SLACK	TEMPERATURE	SALINITY	DISSOLVED OXYGEN
140574	OSM01	L	N	N	N
210574	OSM02	H	T	S	D
130674	OSM03	L	T	S	D
110774	OSM04	L	T	S	N
290774	OSM05	H	T	S	D
020874	OSM06	H	T	S	D
050874	OSM07	L	T	S	D
090974	OSM08	L	T	S	D
081074	OSM09	L	T	S	D
141174	OSM10	H	T	S	D
051274	OSM11	L	T	S	N
180475	OSM01	L	T	N	D
090575	OSM02	H	T	S	D
011075	OSM03	H	N	N	N
171075	OSM04	H	T	S	D
181175	OSM05	H	T	S	N
130476	OSM01	H	T	S	D
050576	OSM02	L	T	N	D
260576	OSM03	H	T	S	D
090676	OSM04	H	T	S	D
130976	OSM05	L	N	N	N
130976	OSM06	H	N	N	N
240976	OSM07	L	T	S	D
180577	OSM01	L	T	S	D
070677	OSM02	L	T	S	D
050777	OSM03	L	T	S	D
270777	OSM04	H	T	S	D
050877	OSM05	L	T	S	D
120977	OSM06	H	T	S	D
140977	OSM07	L	N	S	D
041077	OSM08	L	T	S	D
240578	OSM01	L	T	N	D
120678	OSM02	L	T	S	D
190778	OSM03	H	T	S	D
210878	OSM04	L	T	S	D
190978	OSM05	L	T	S	D
111078	OSM06	L	T	S	D

H: HIGH WATER SLACK,
SLACK BEFORE EBB

T: TEMPERATURE GENERATED

S: SALINITY GENERATED

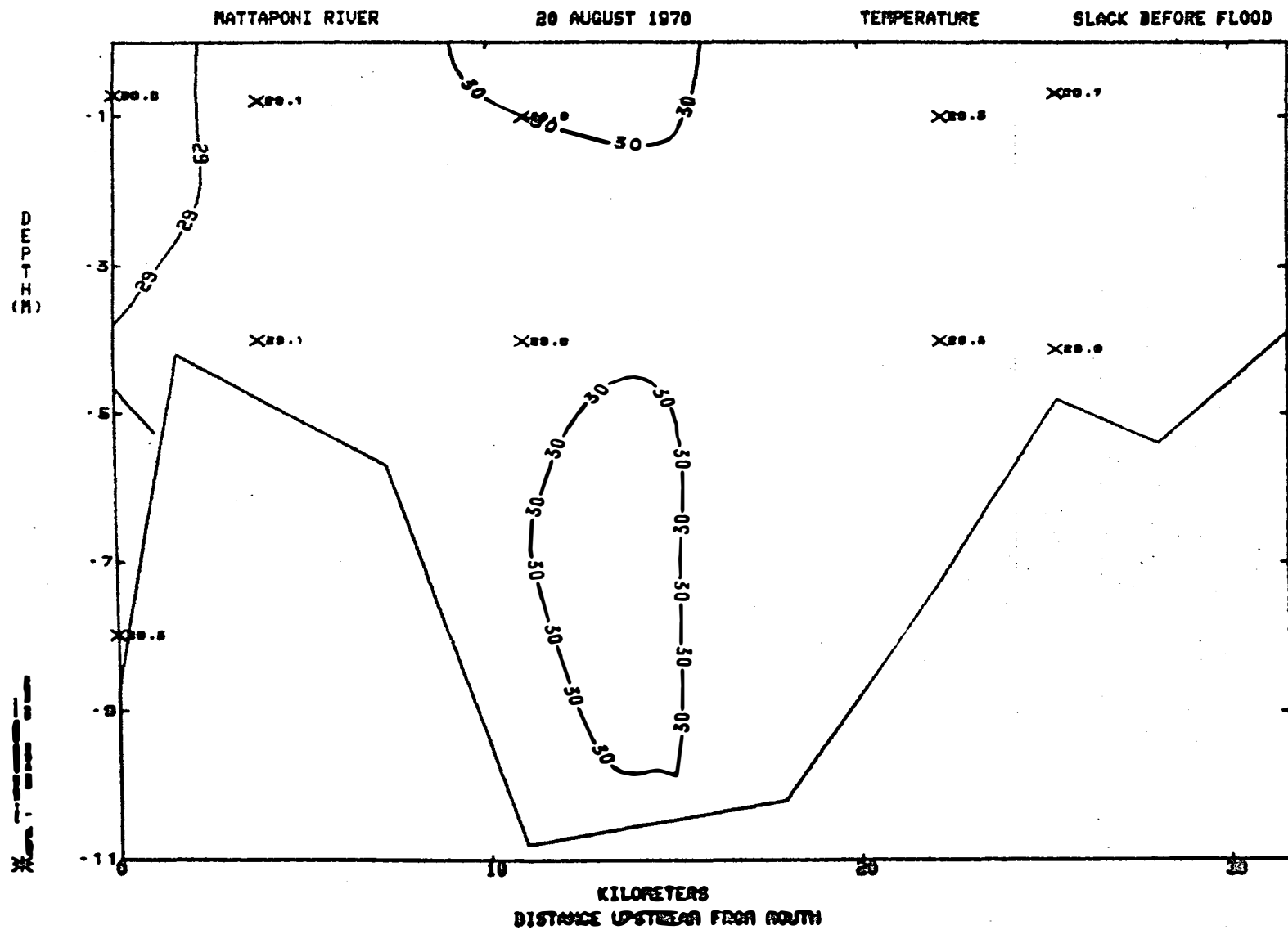
L: LOW WATER SLACK,
SLACK BEFORE FLOOD

D: DISSOLVED OXYGEN GENERATED

N: NO CONTOUR GENERATED

(NO DATA AVAILABLE OR NOT
ENOUGH TO CONTOUR)

B. Temperature ($^{\circ}\text{C}$)

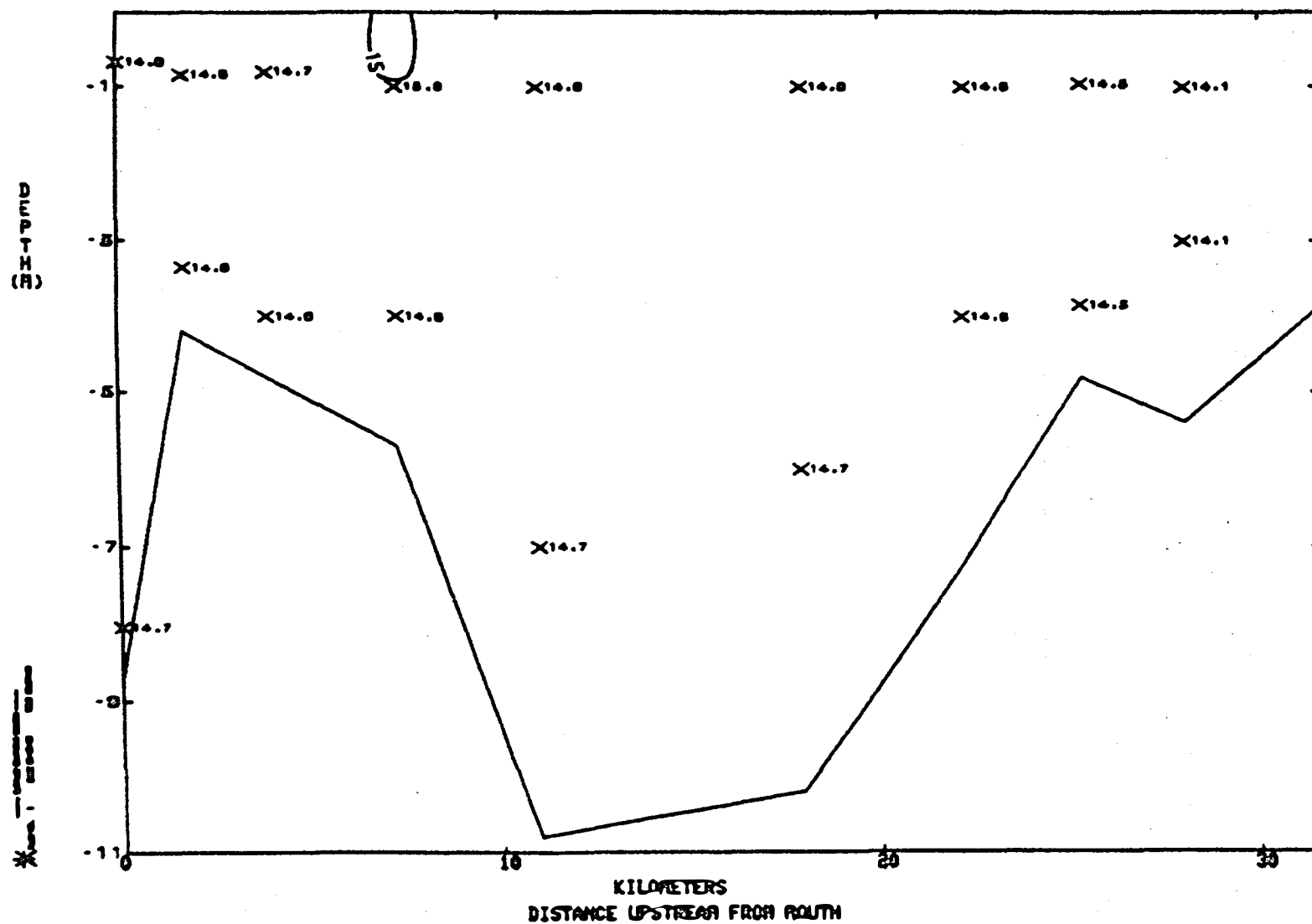


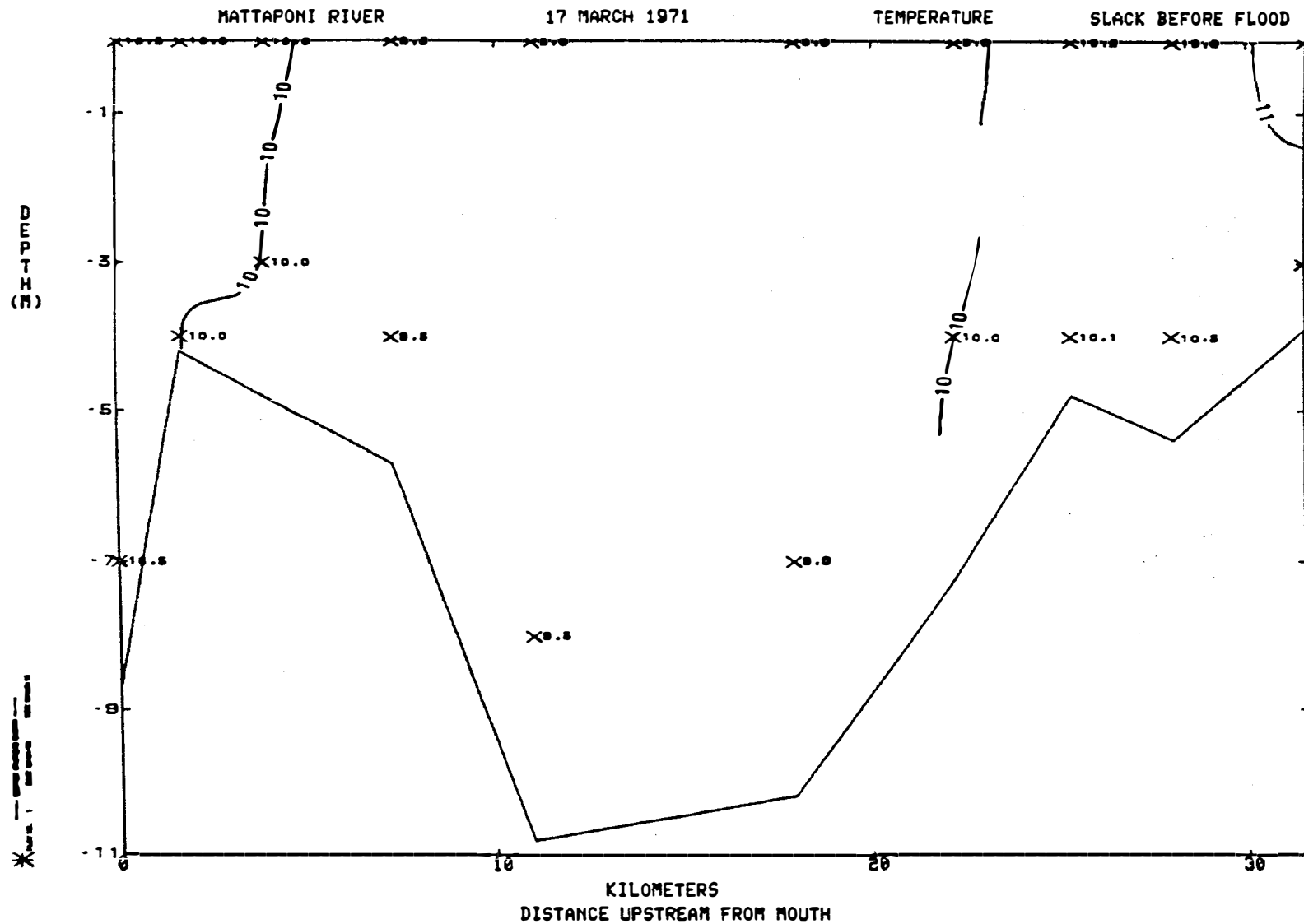
MATTAPONI RIVER

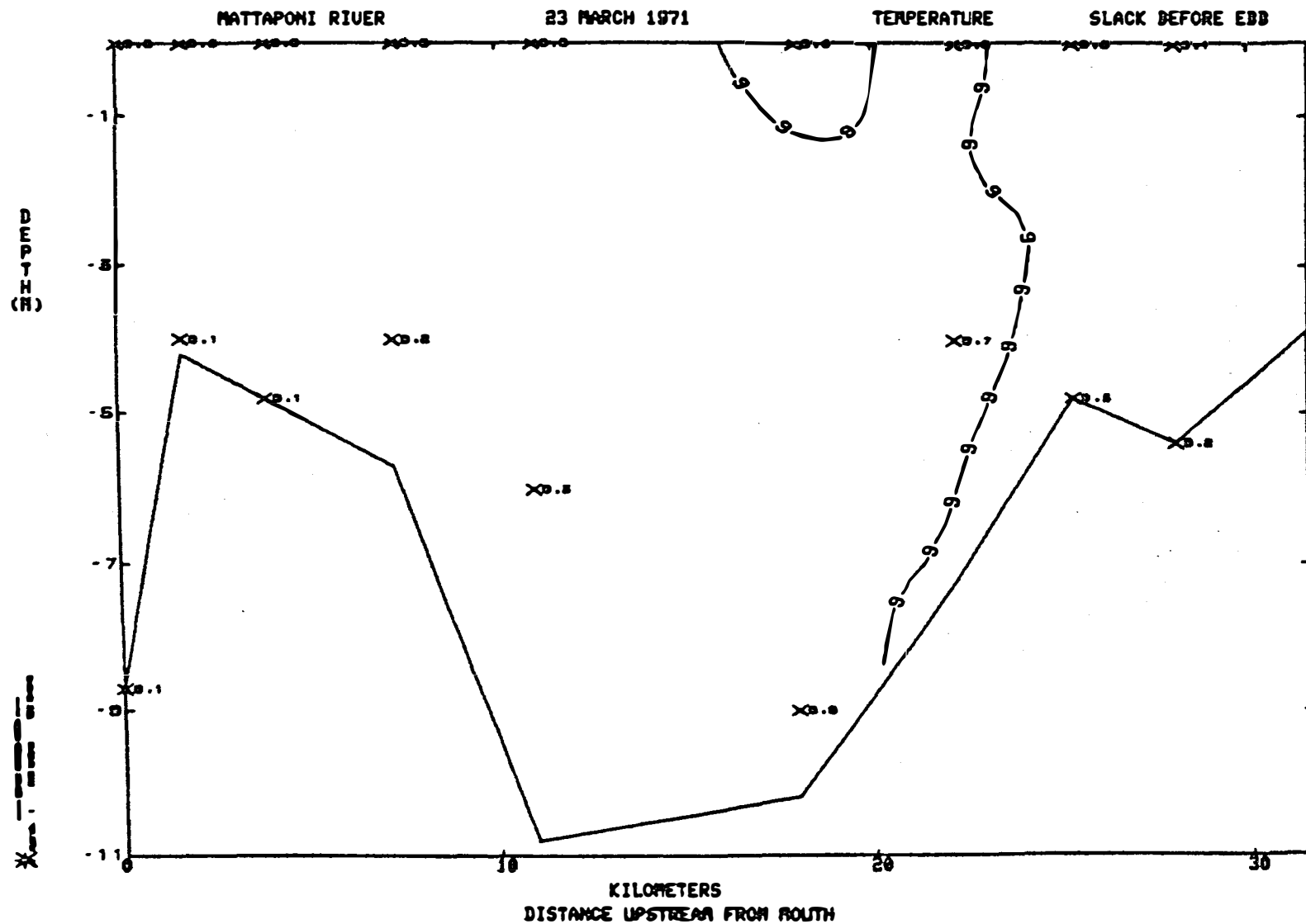
15 NOVEMBER 1970

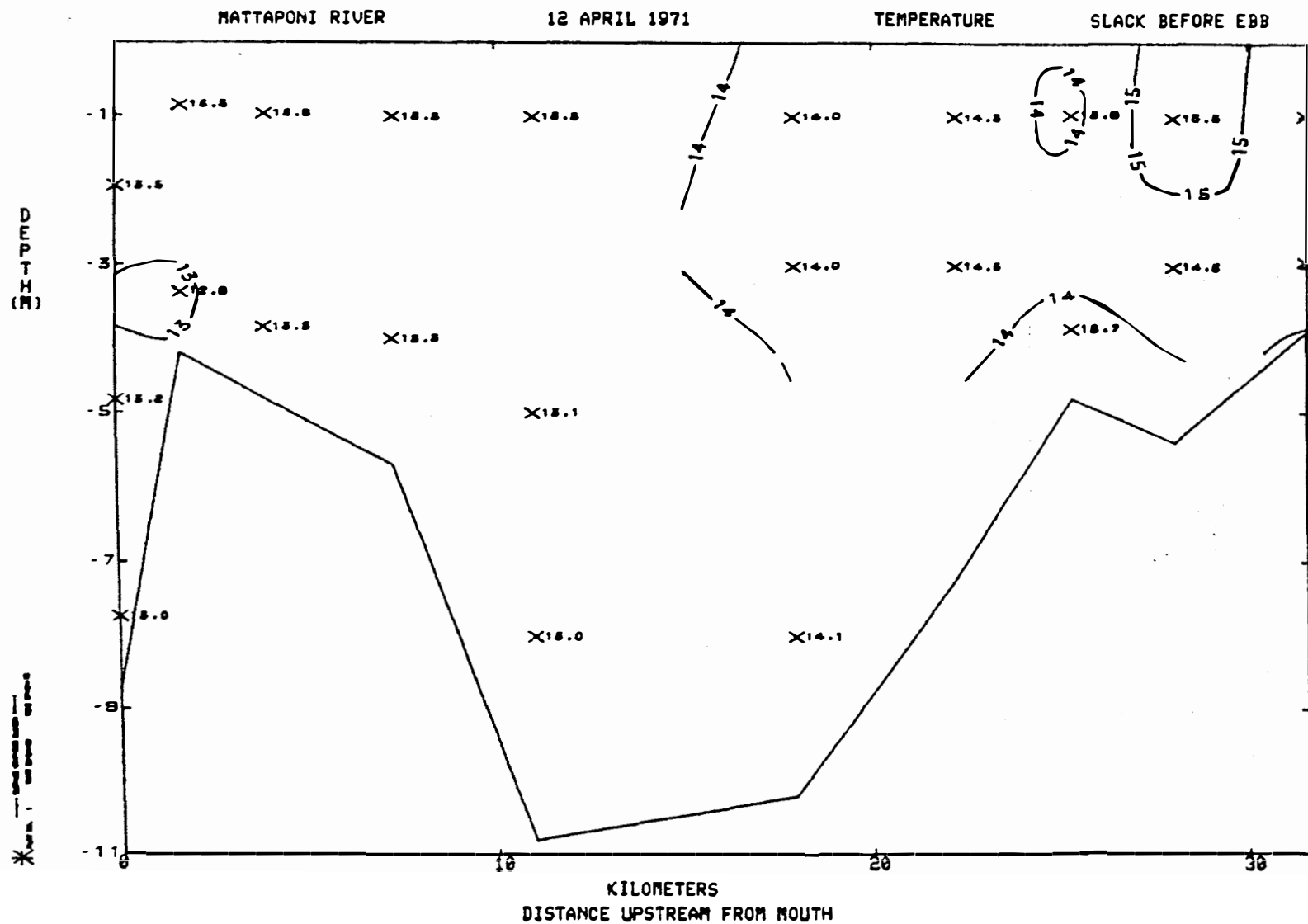
TEMPERATURE

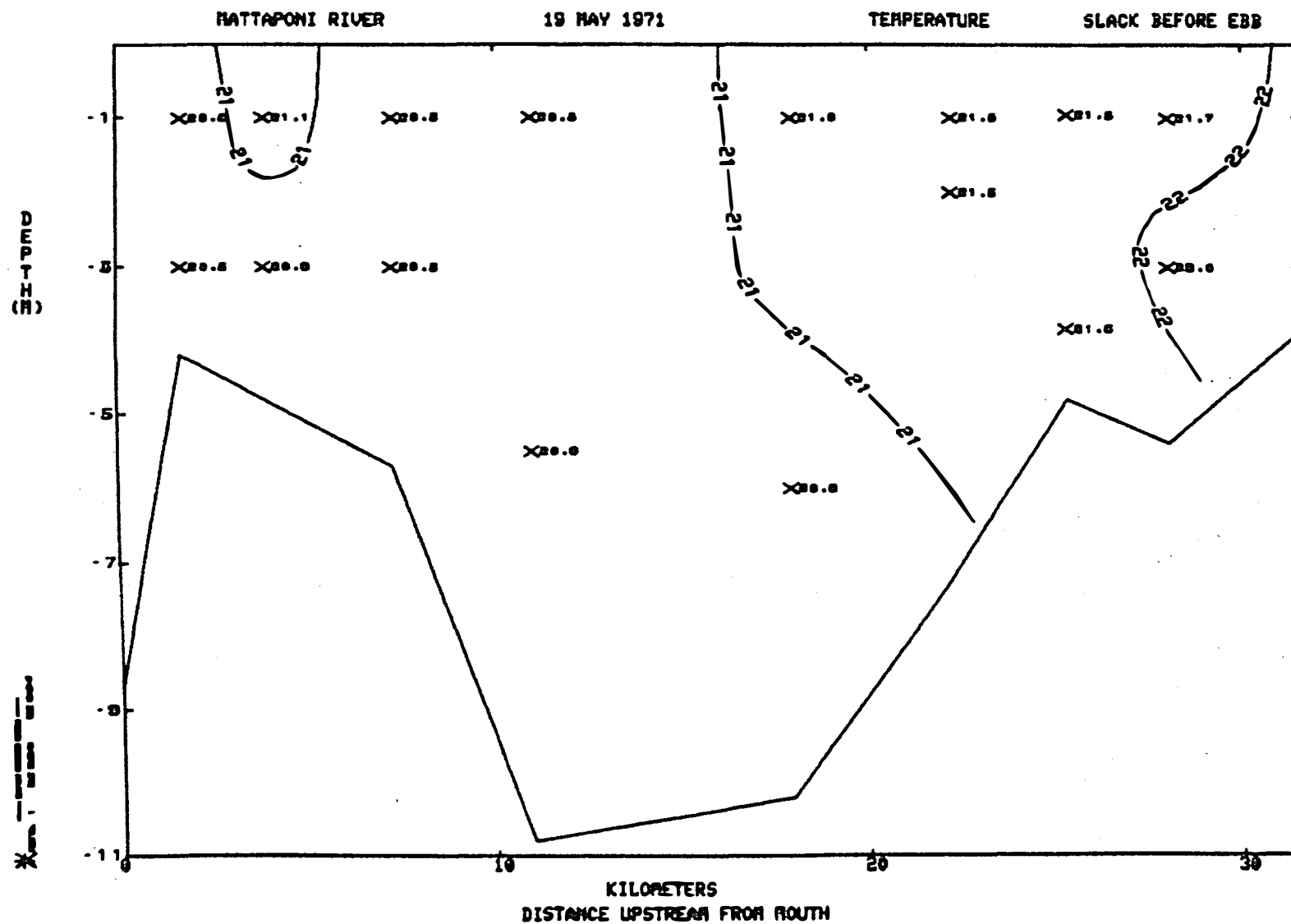
SLACK BEFORE EBB

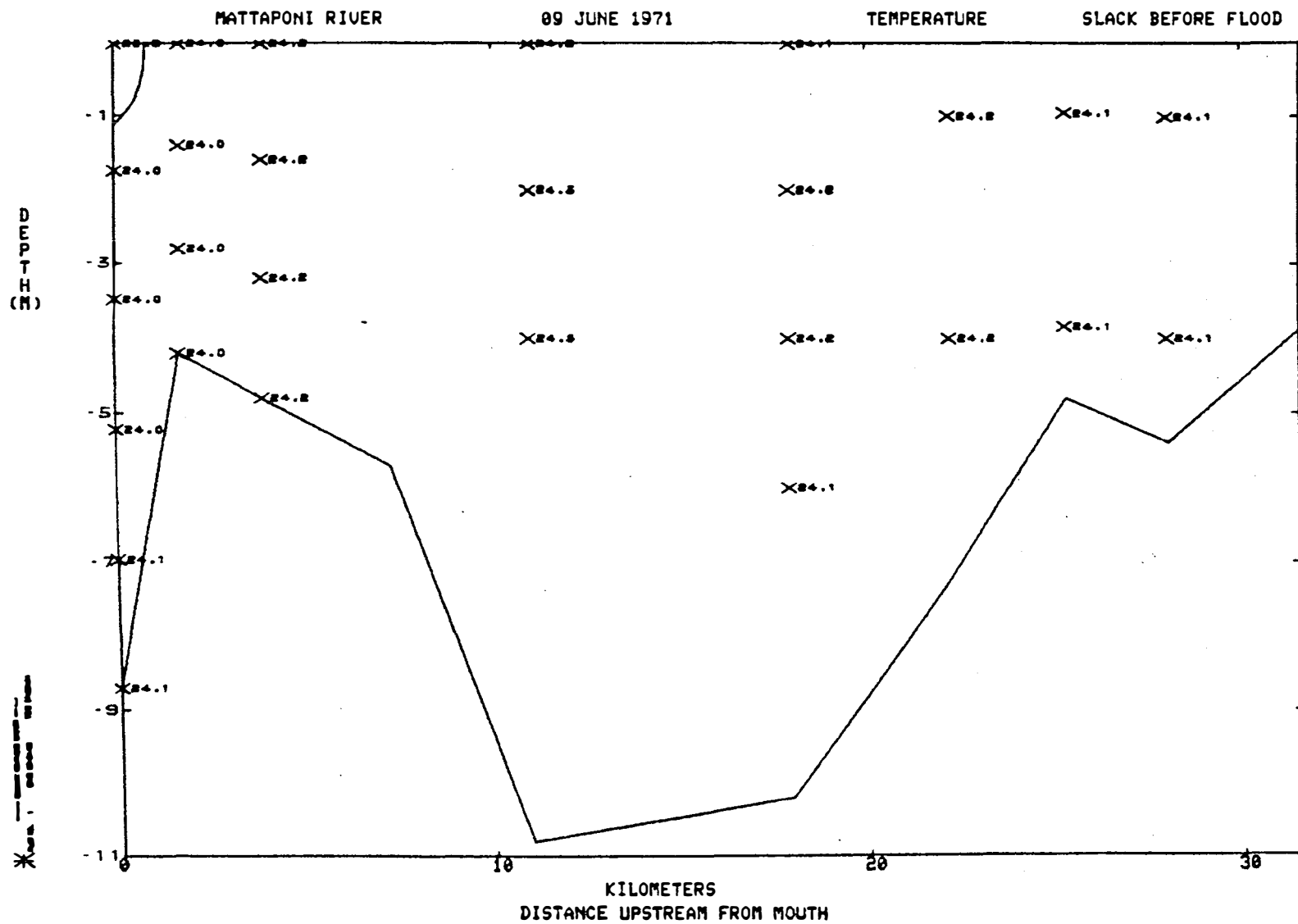


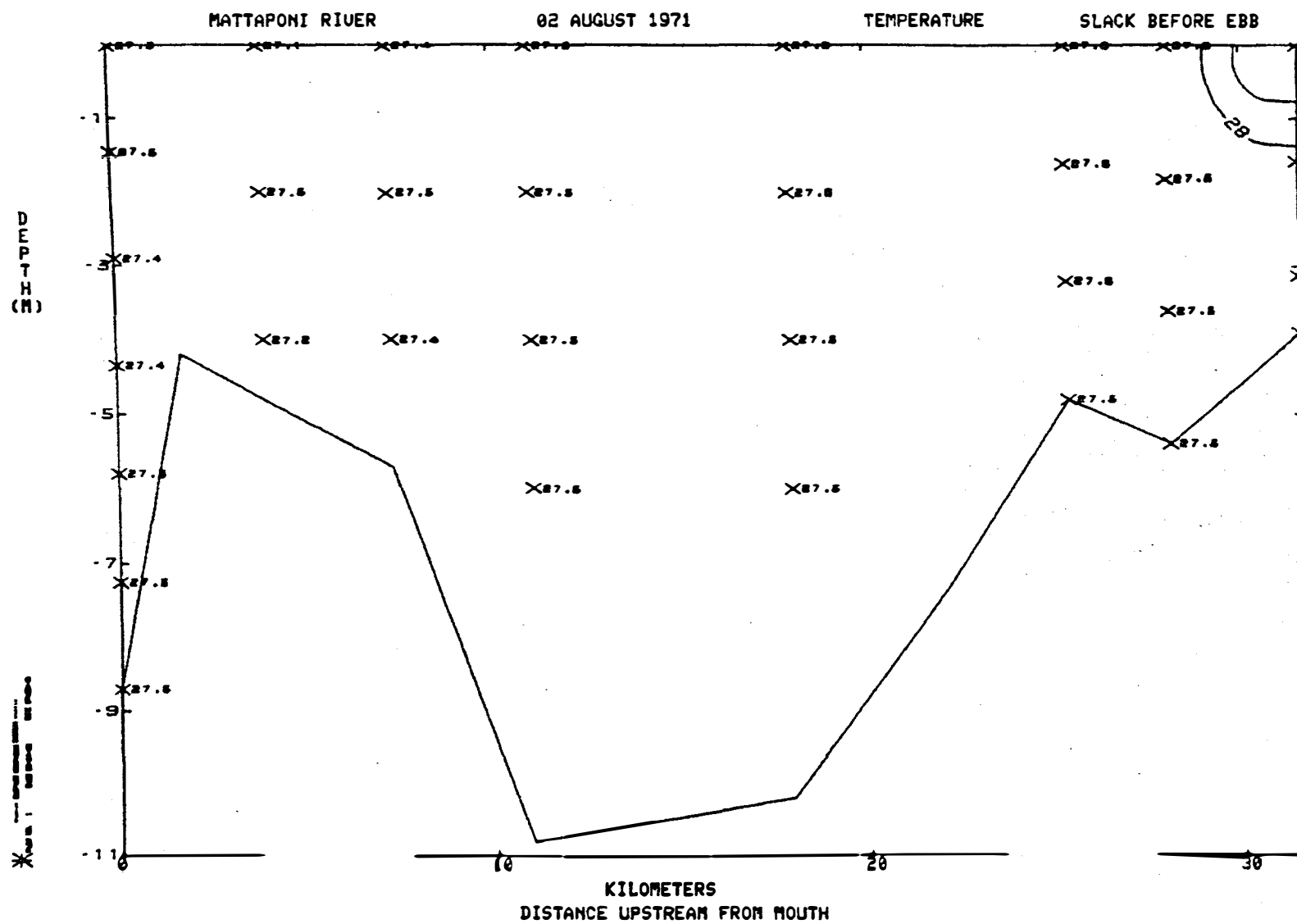


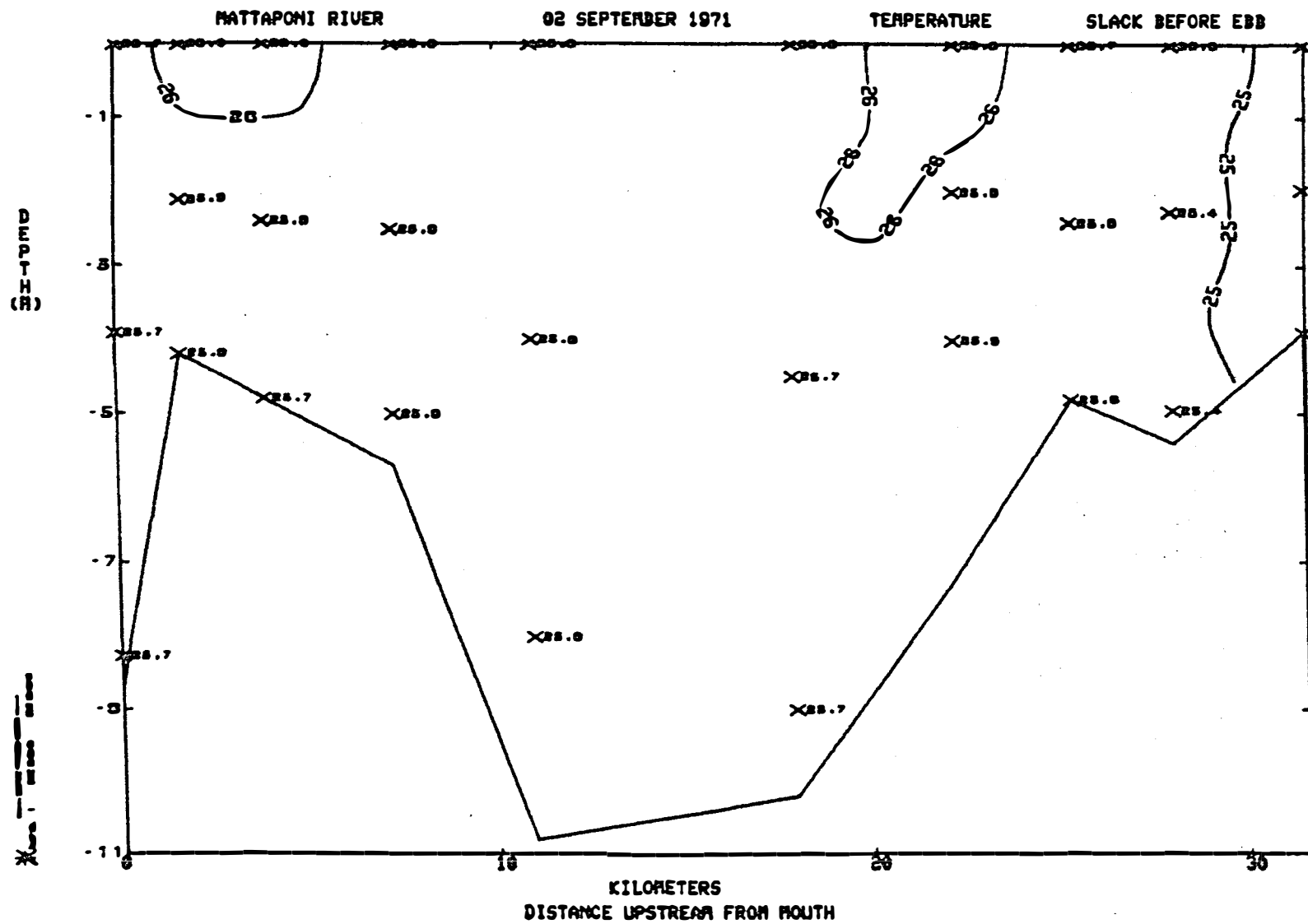


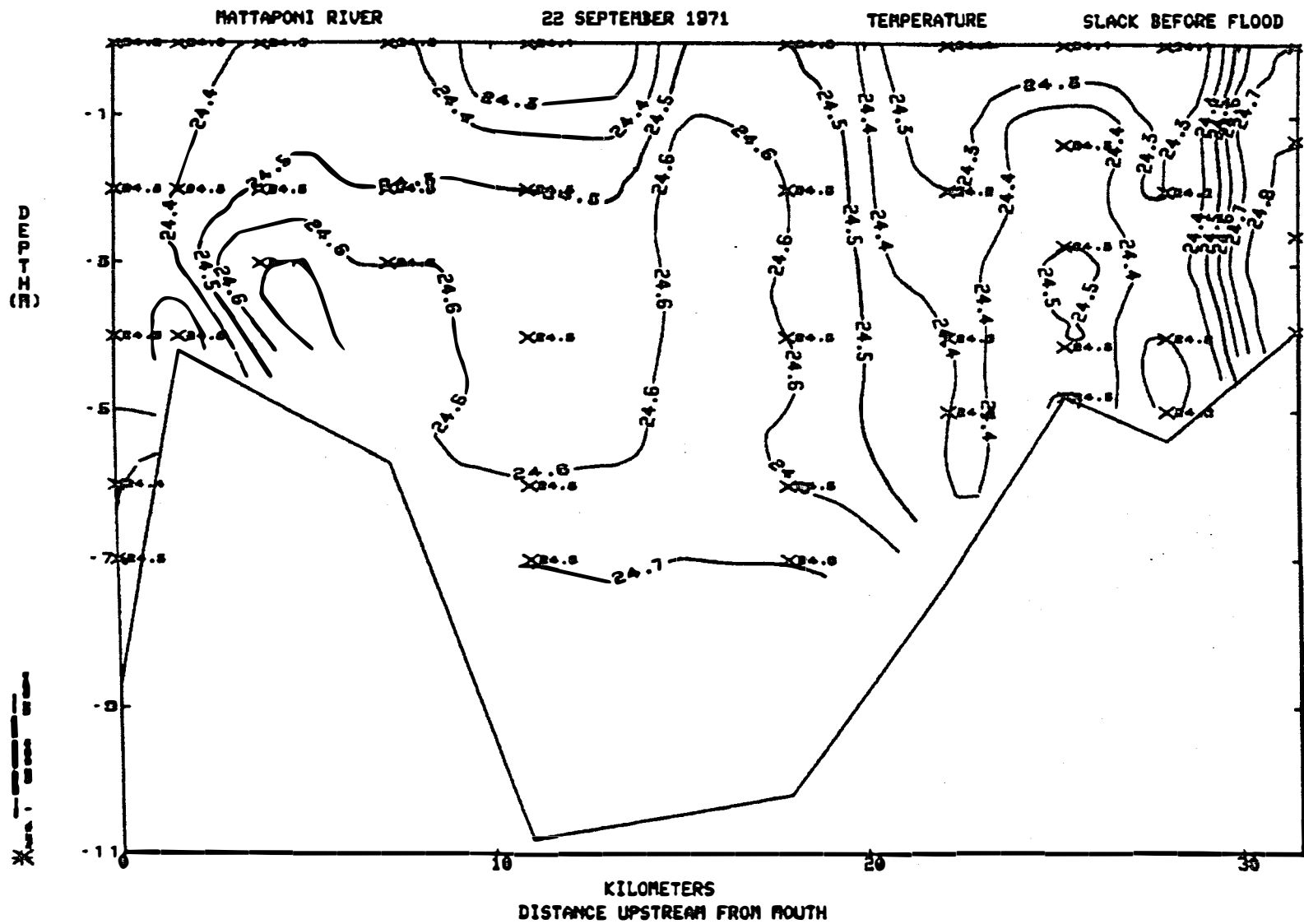


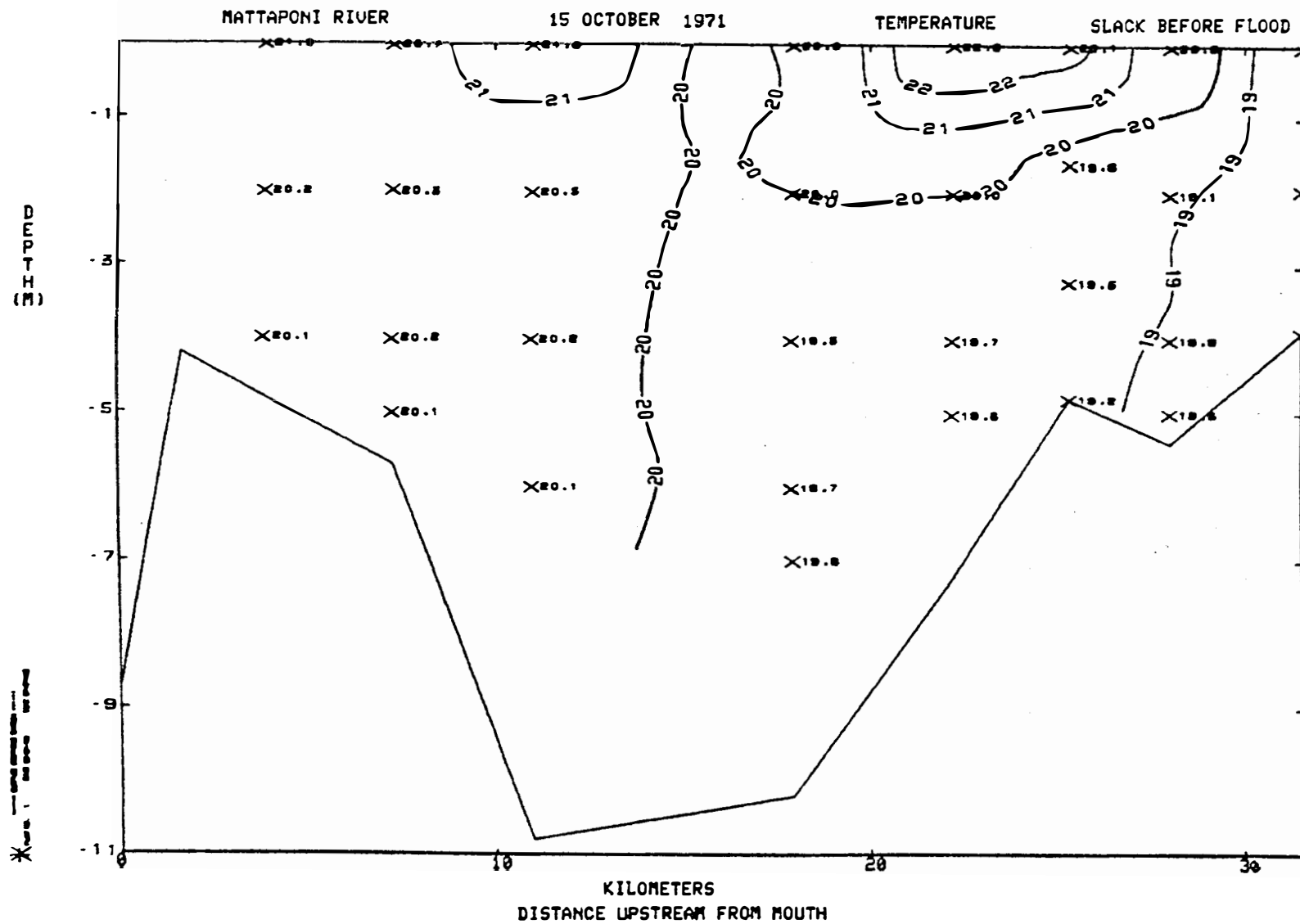


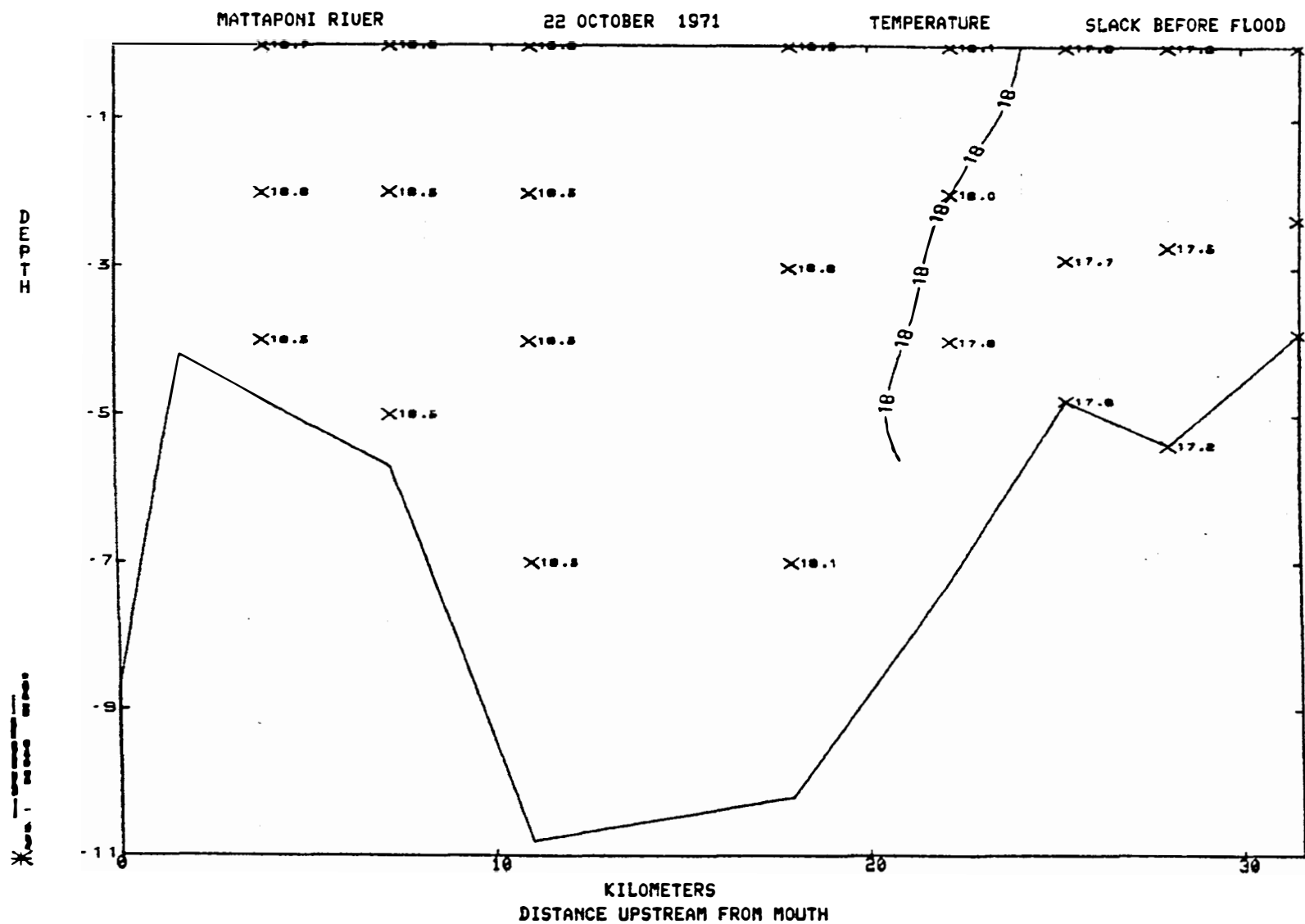


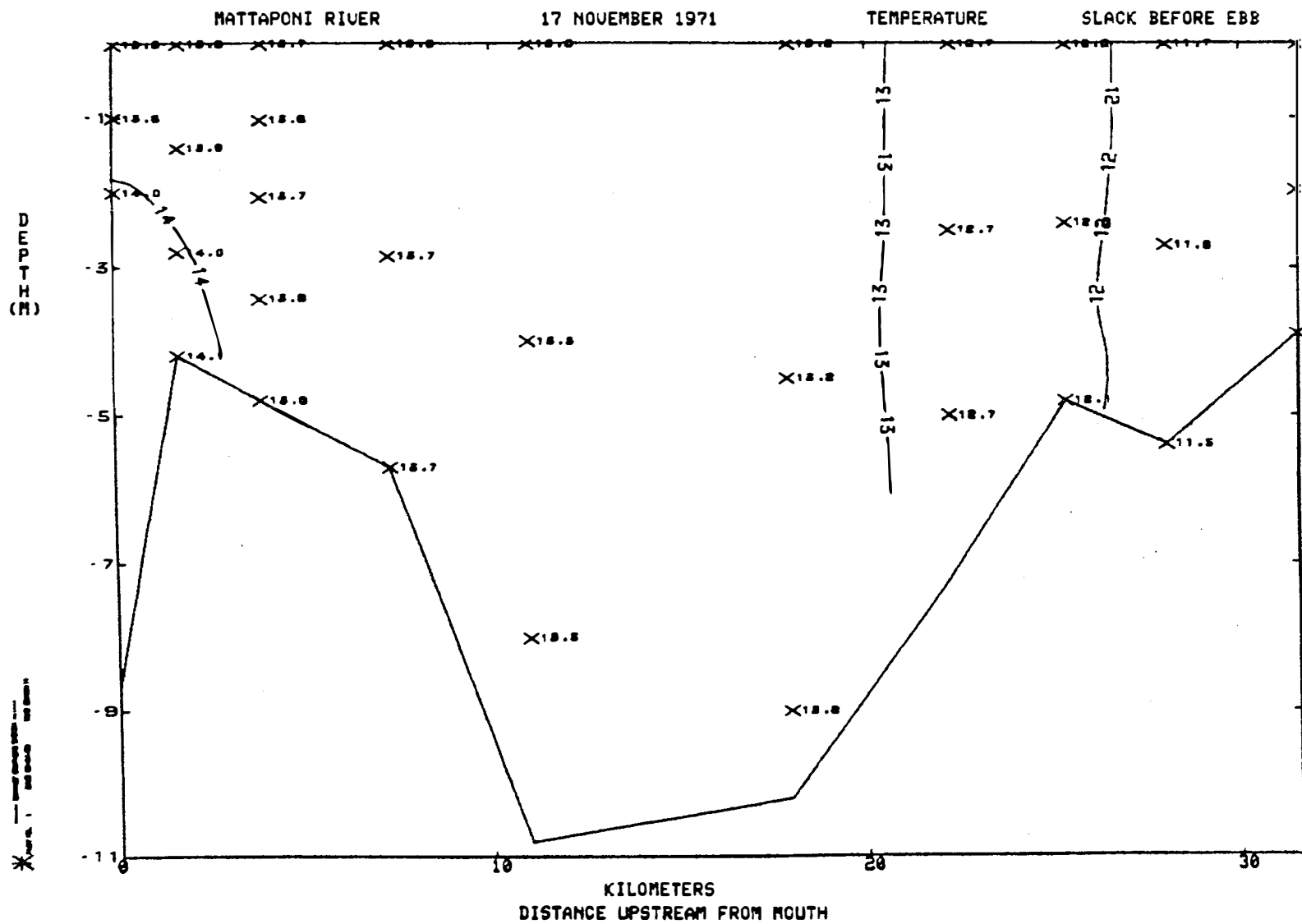


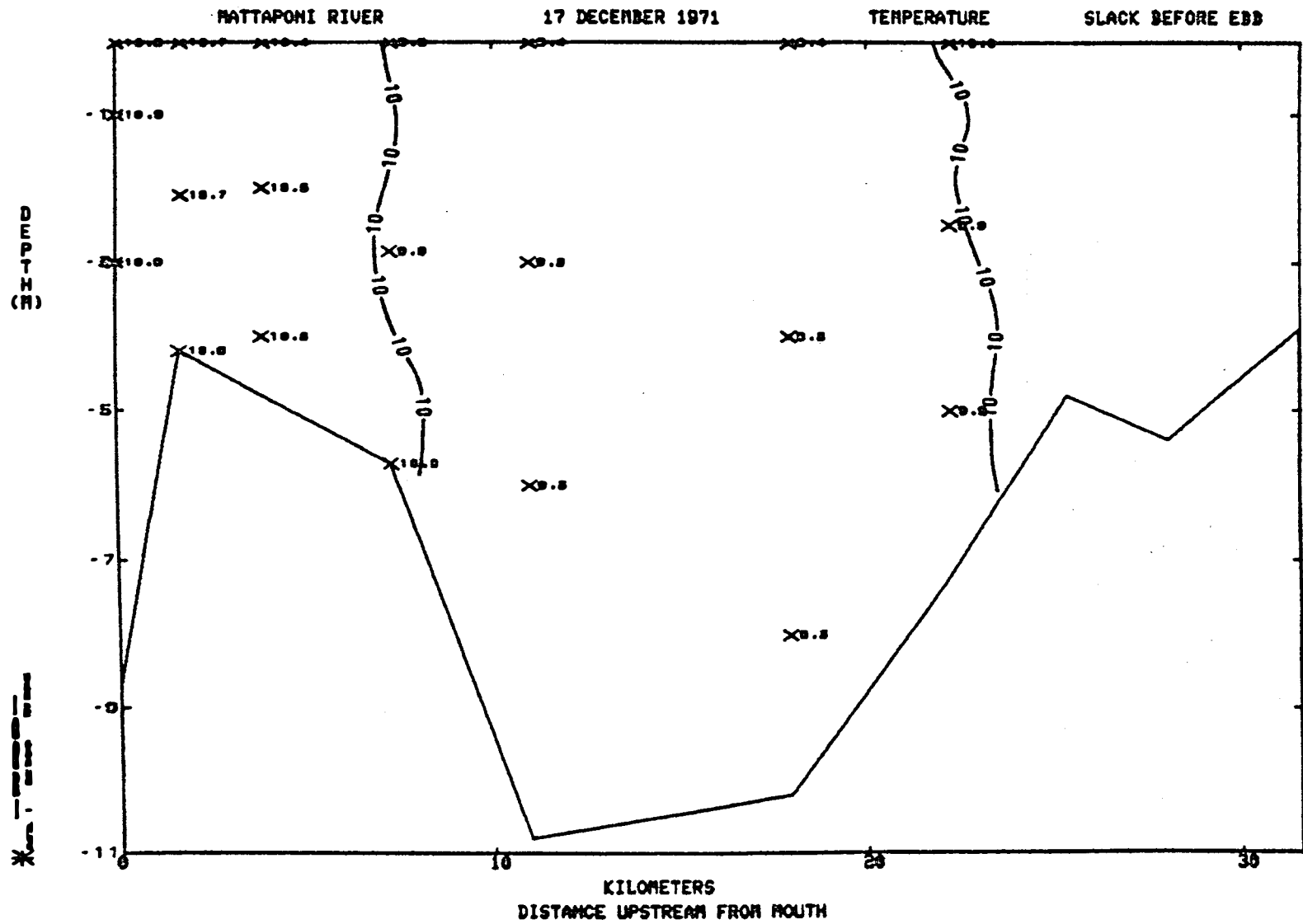


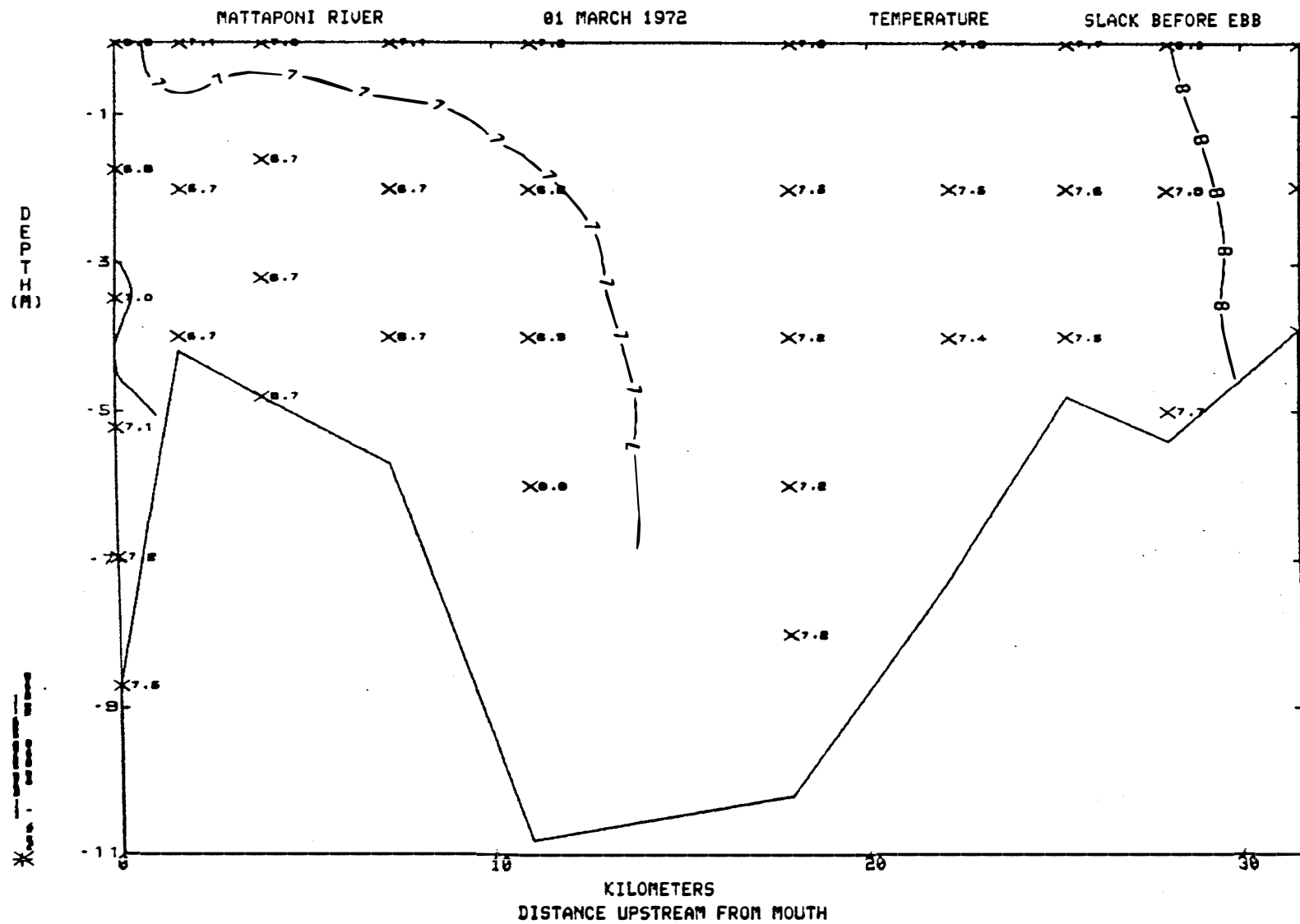


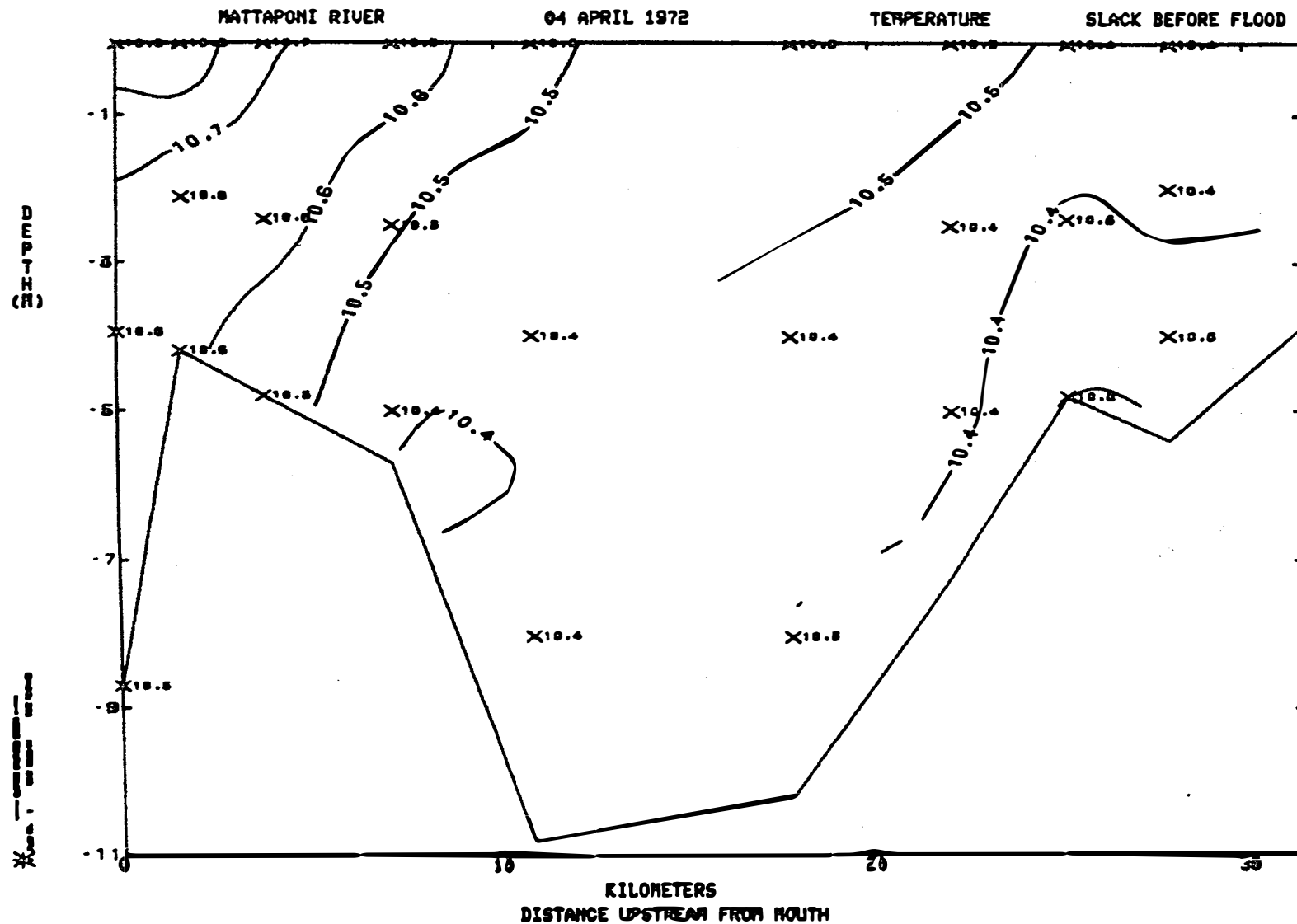


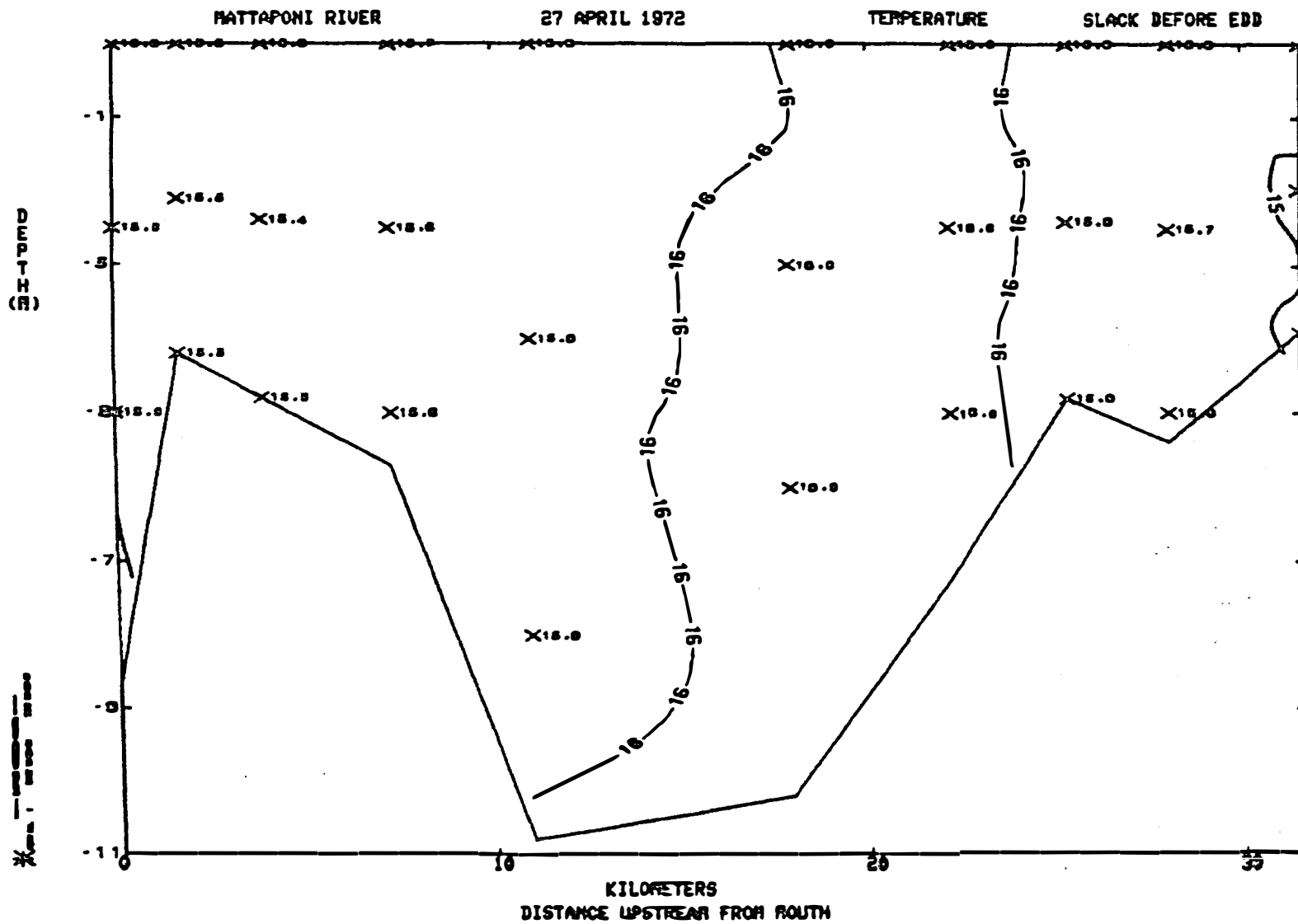


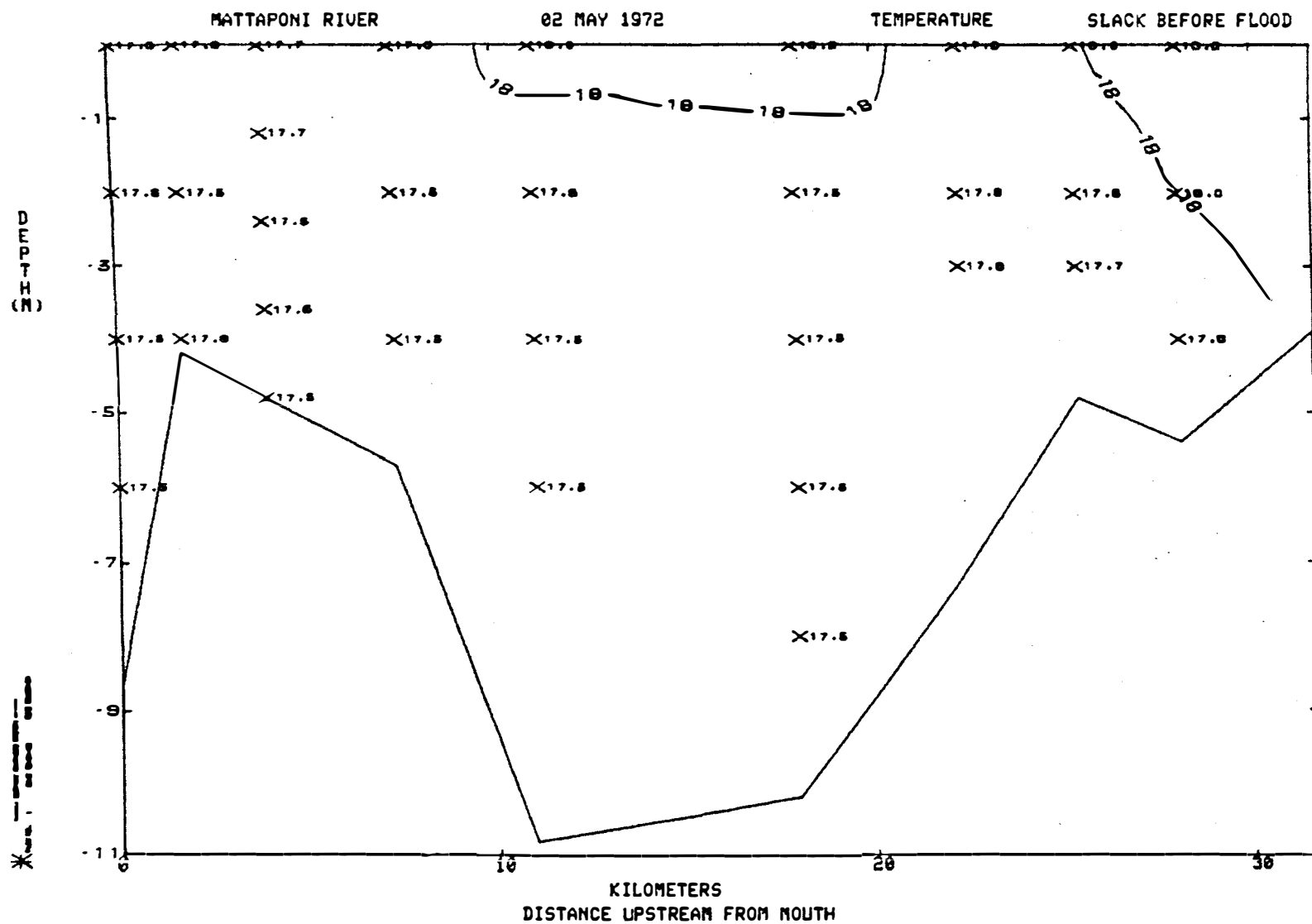


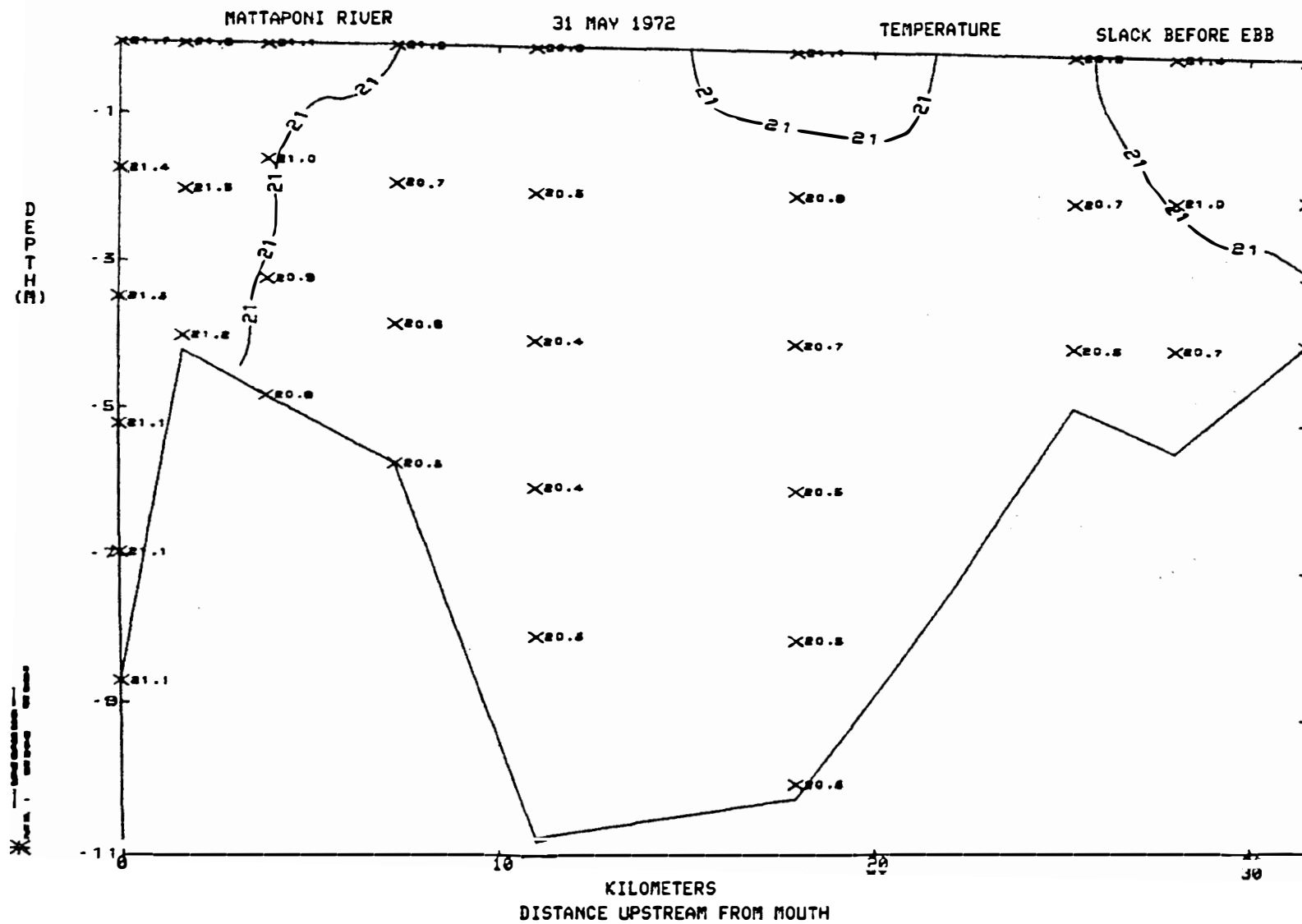


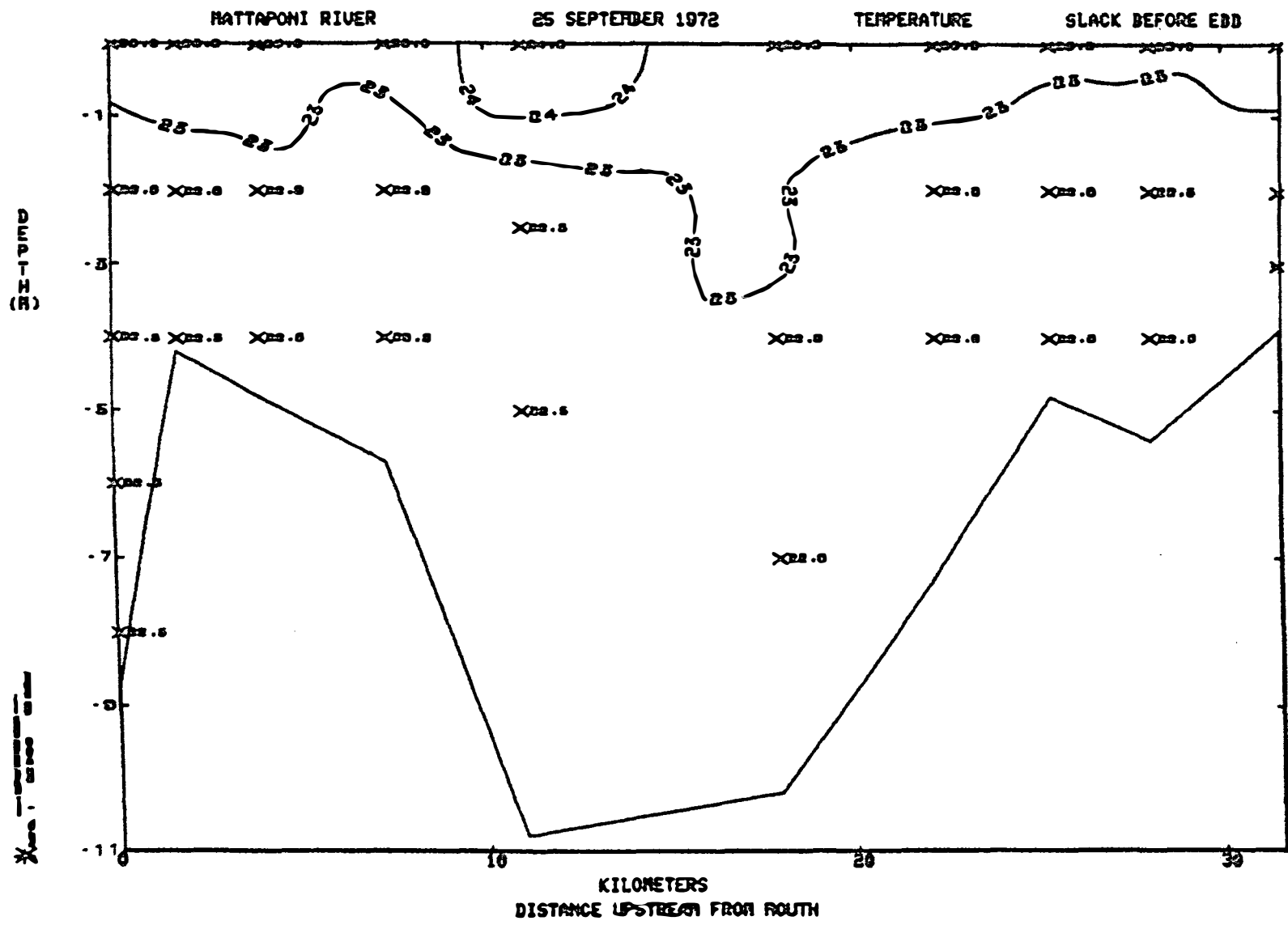


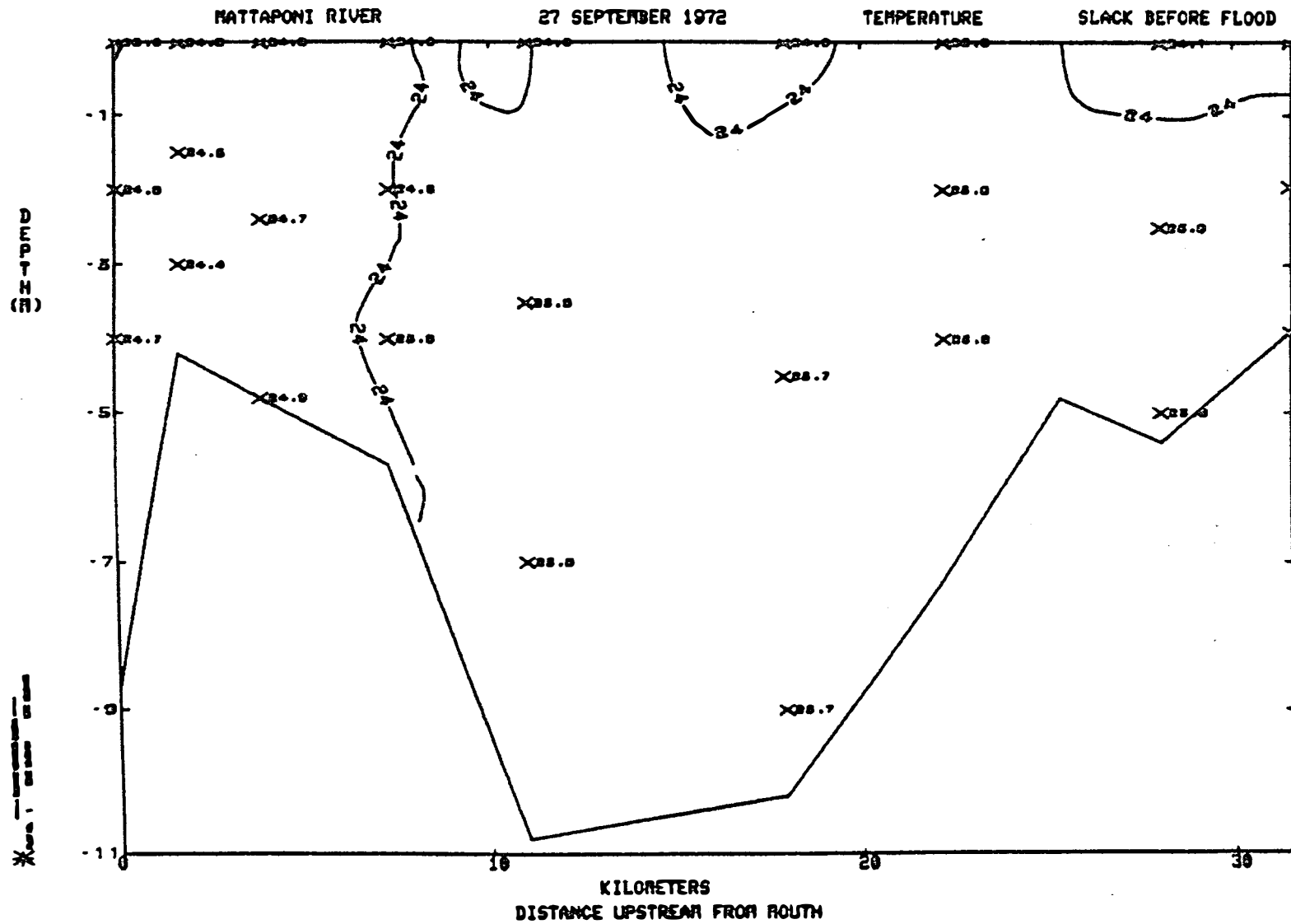


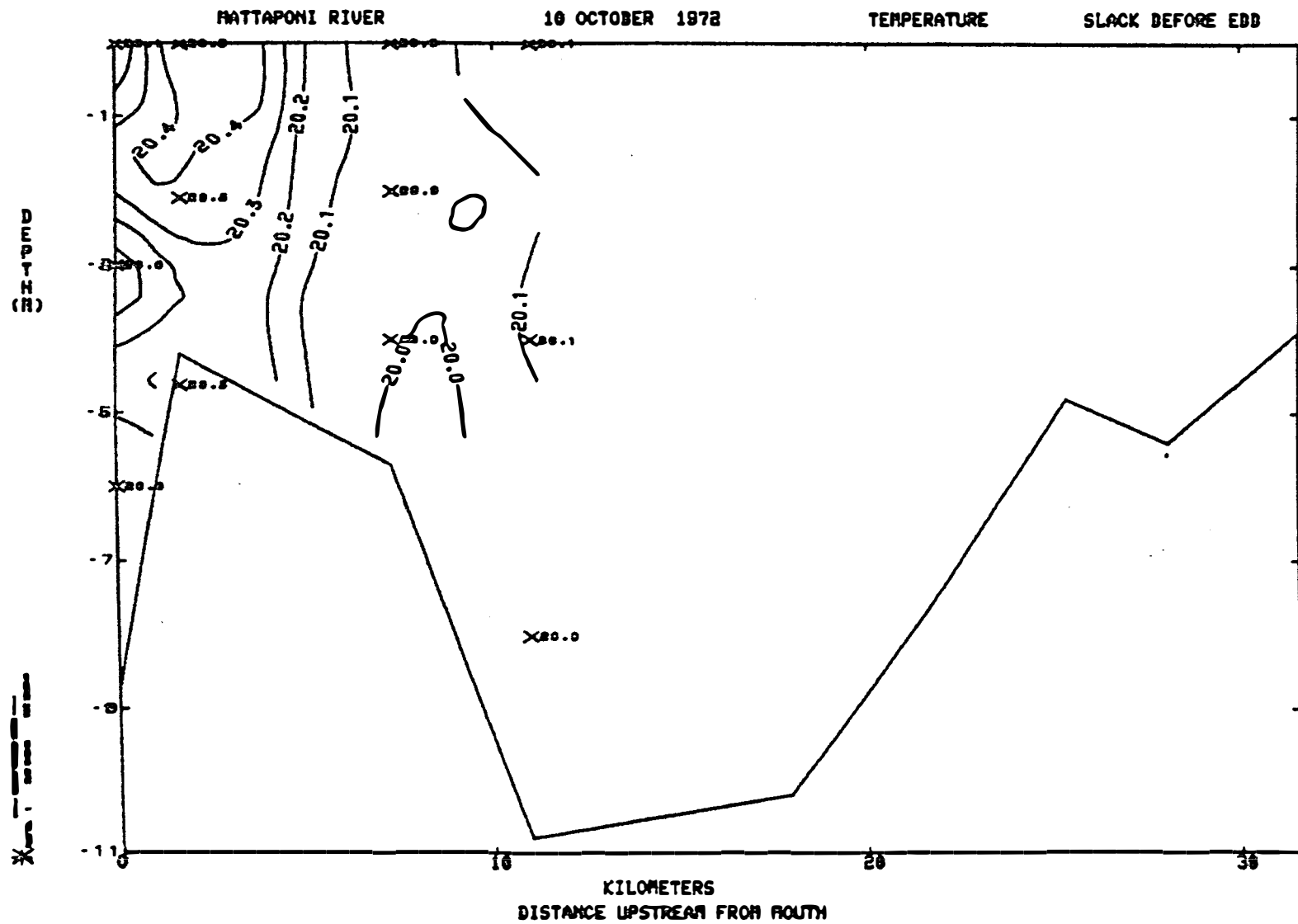


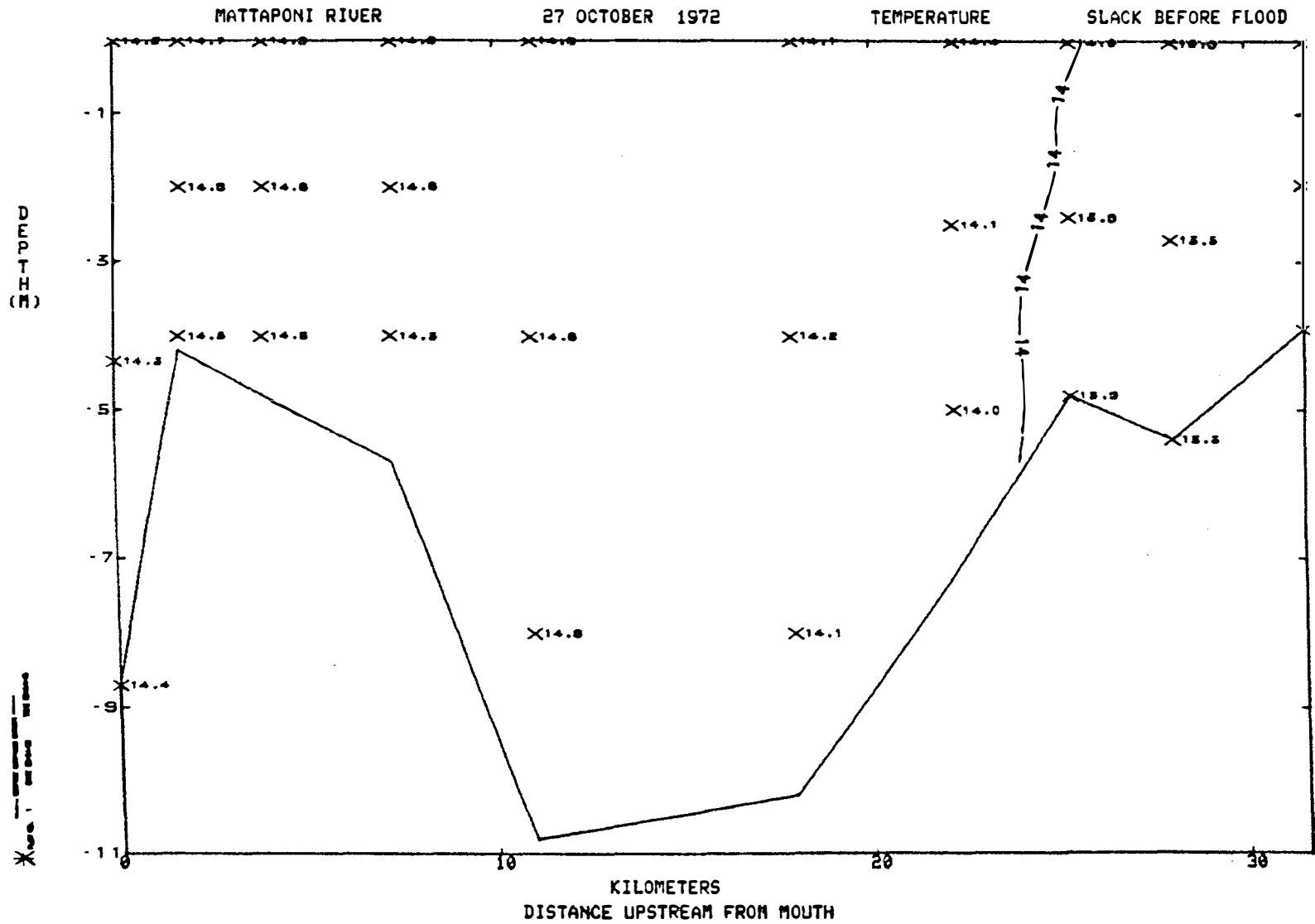


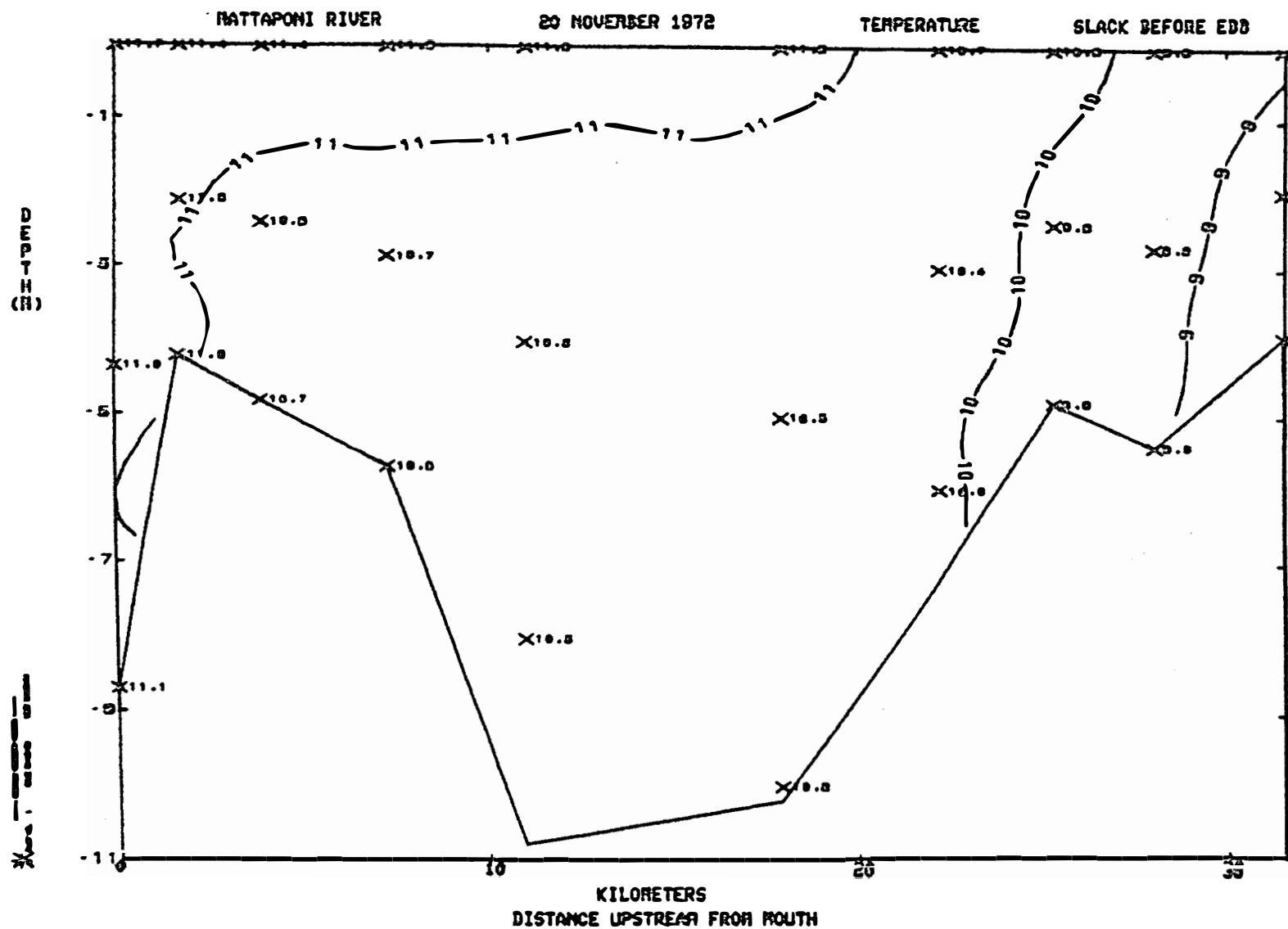


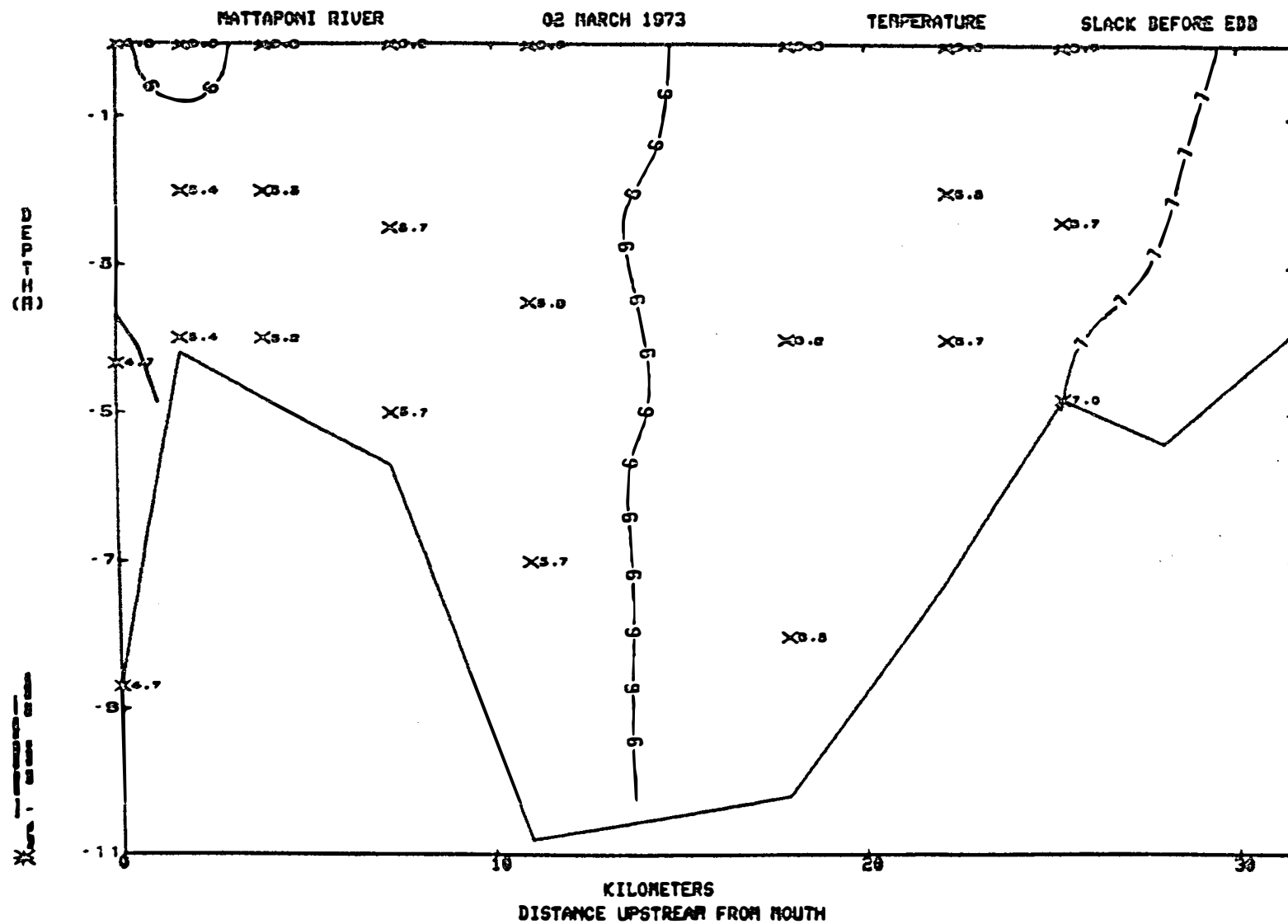


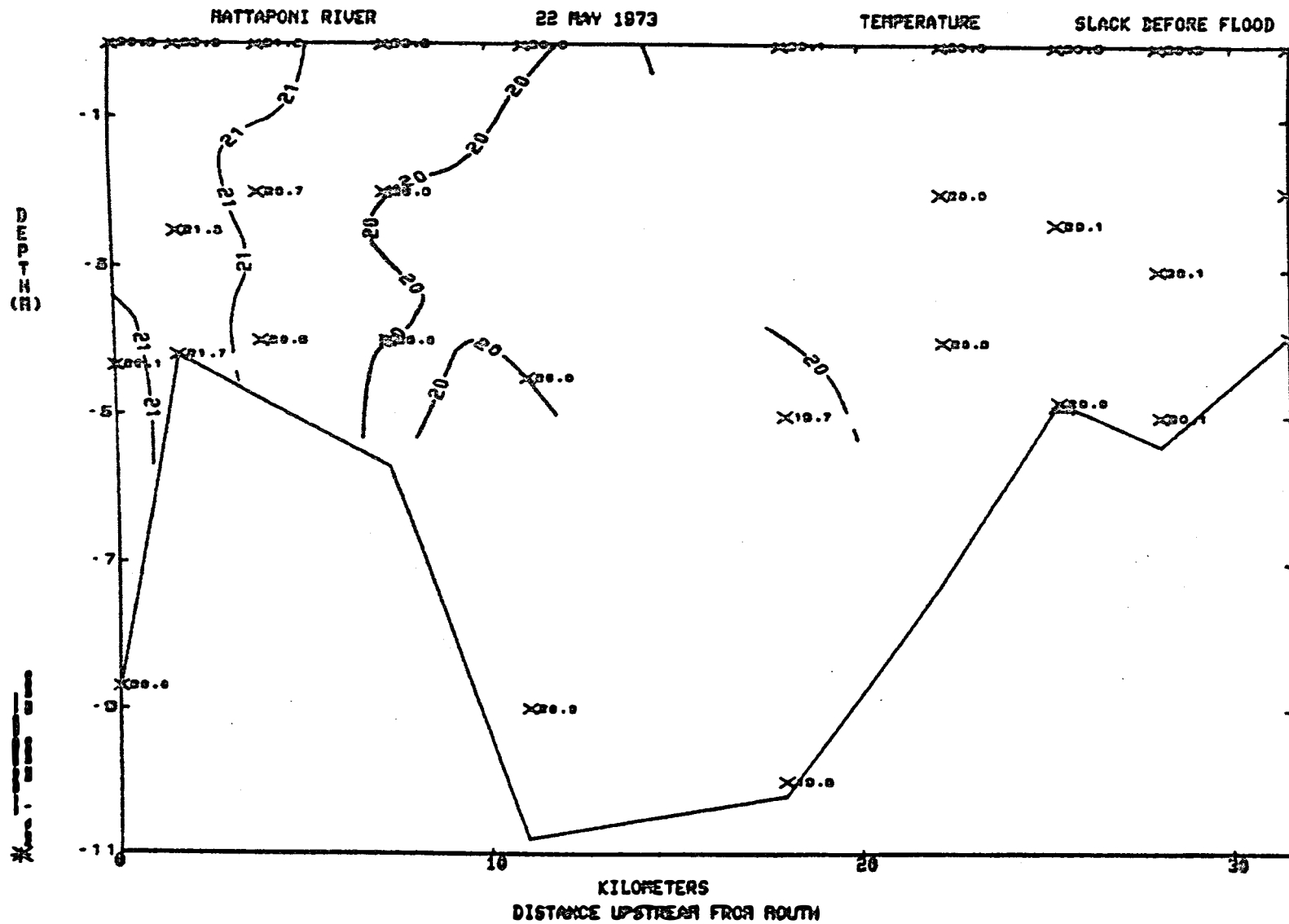


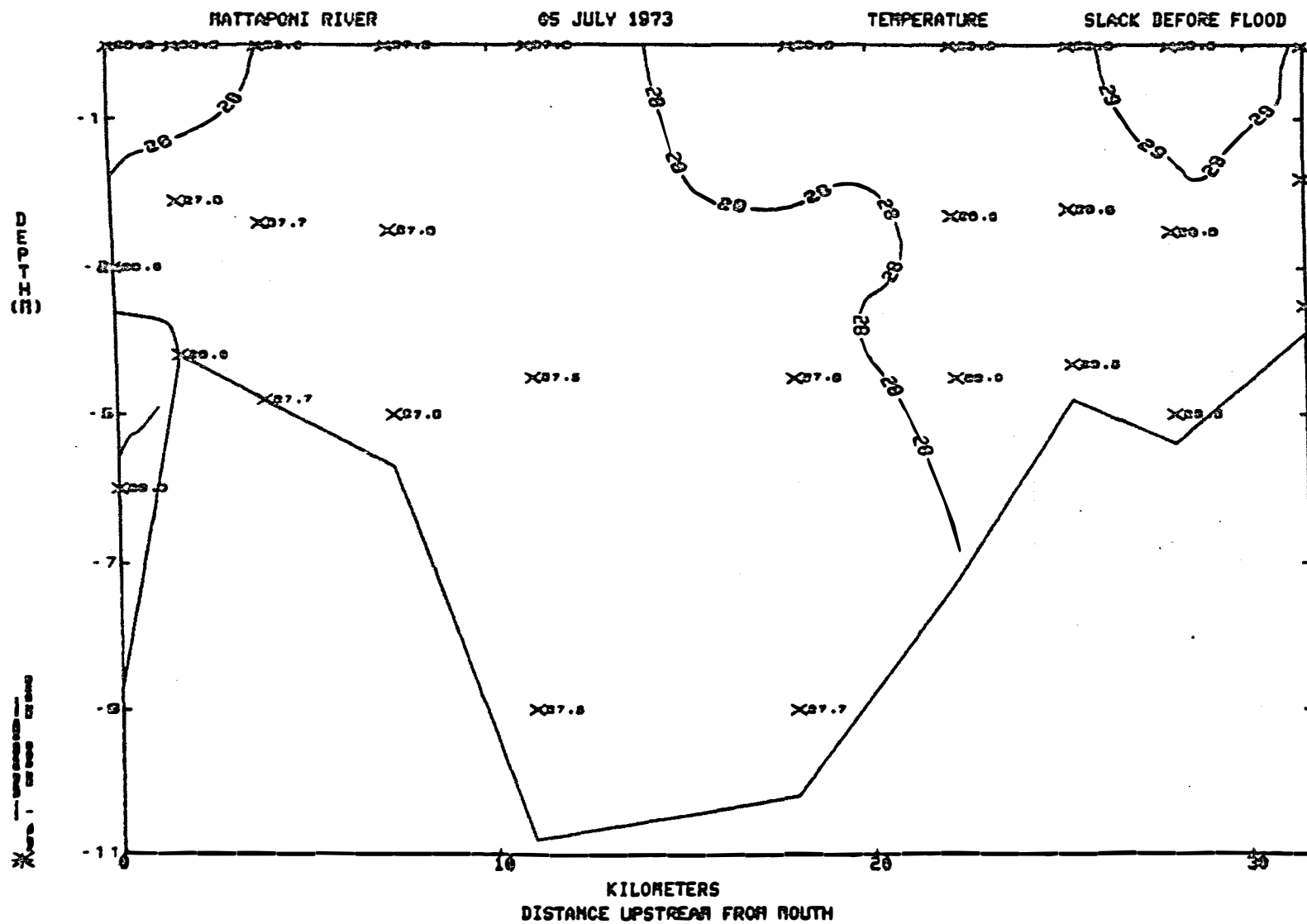


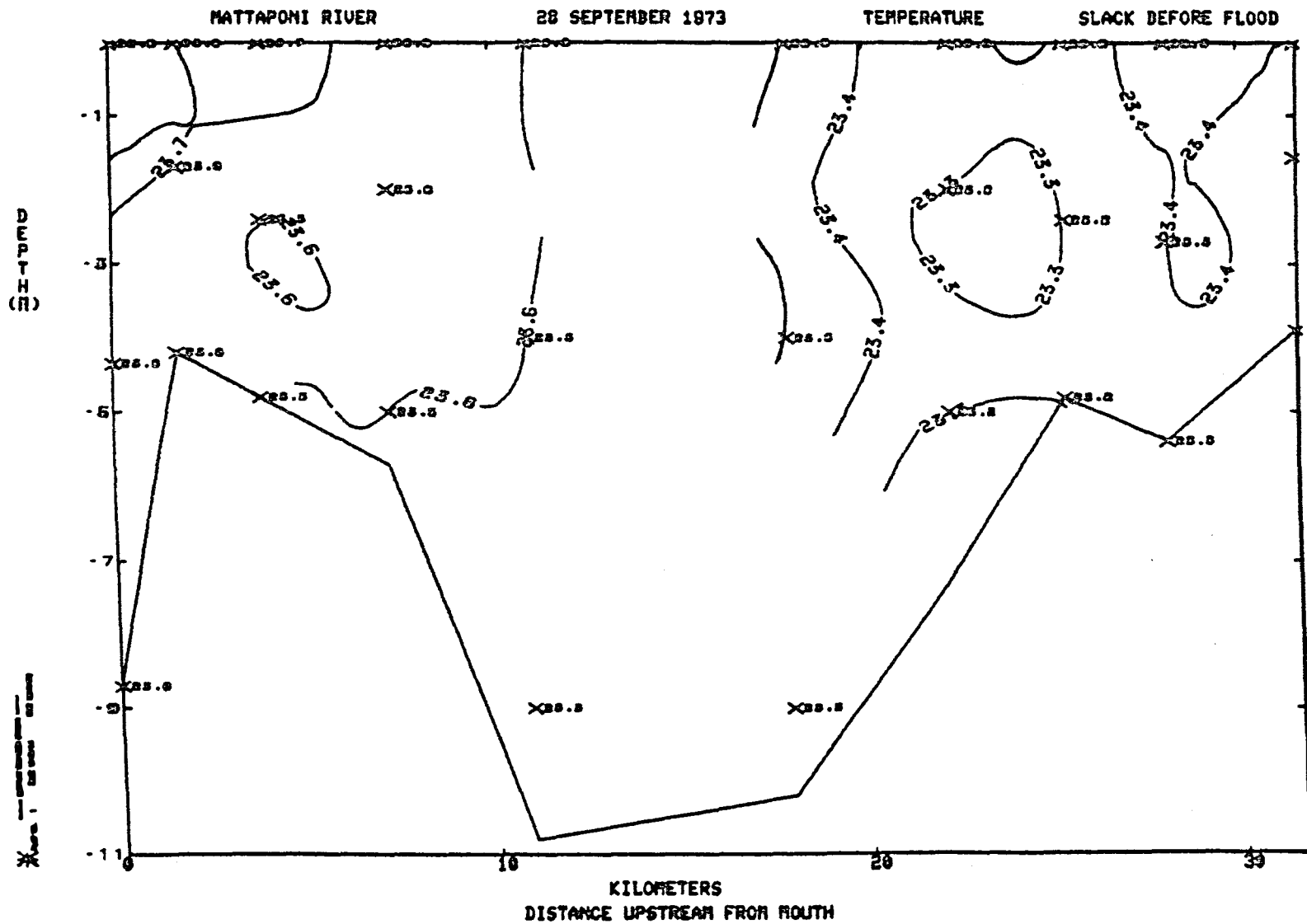


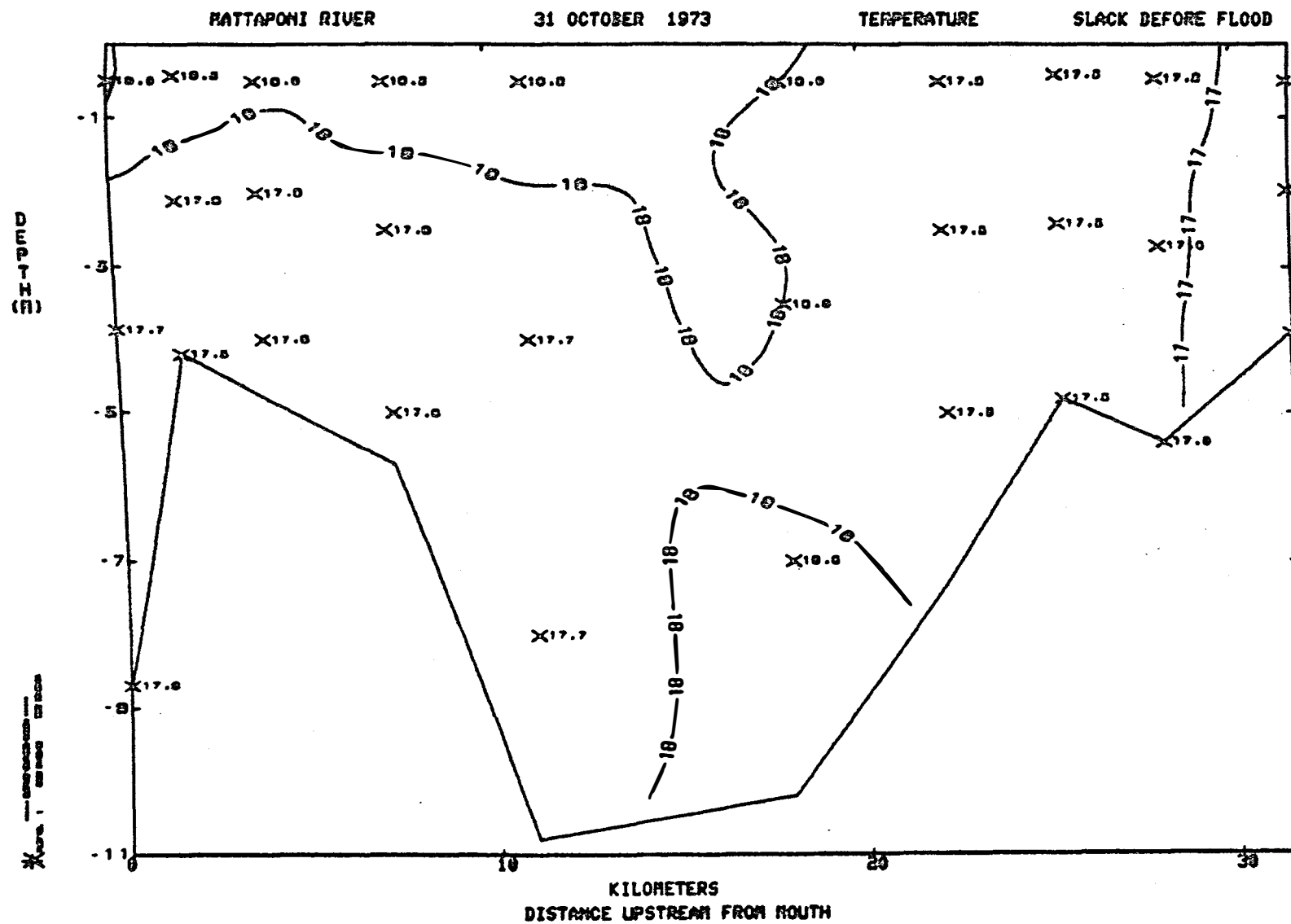


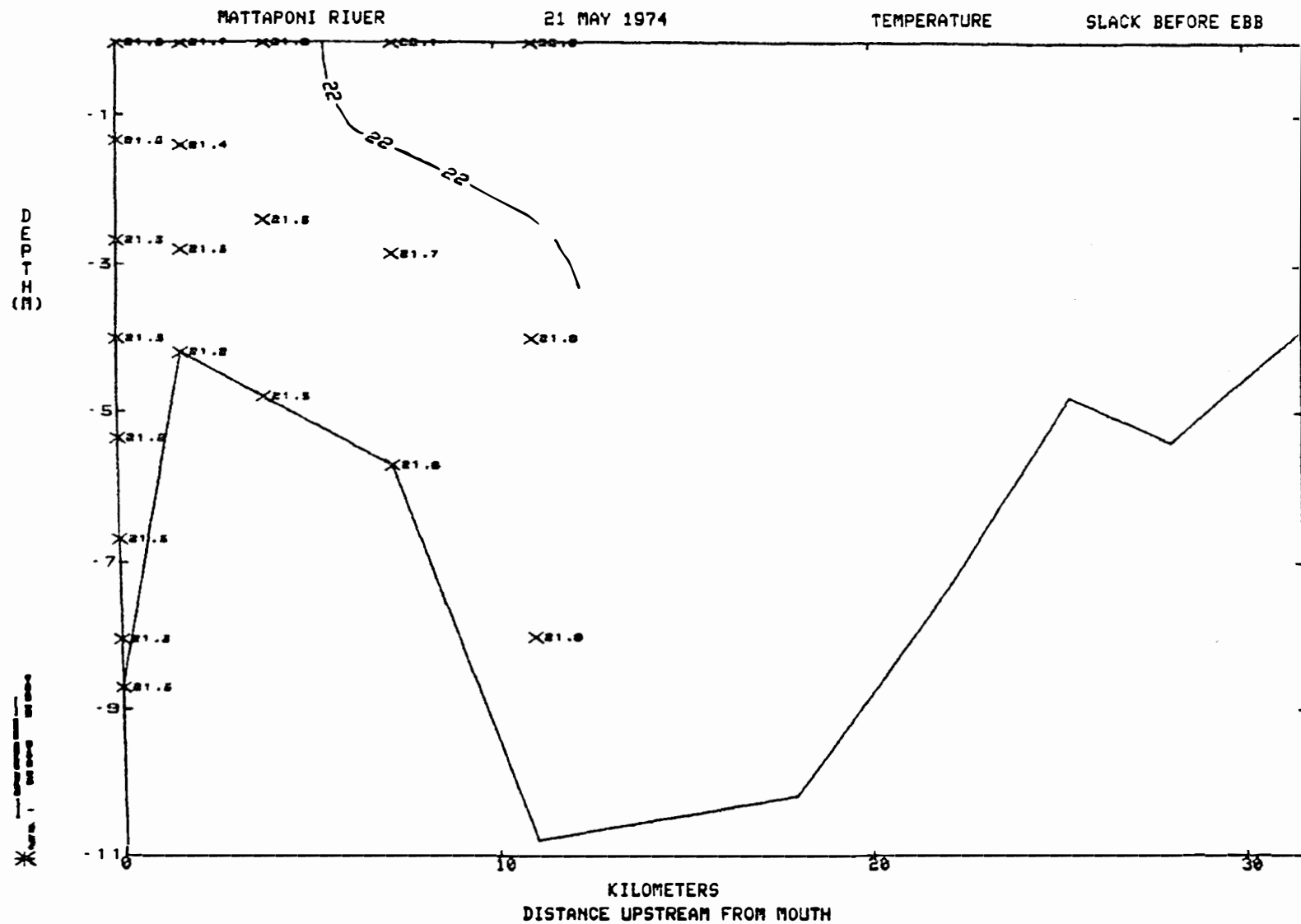


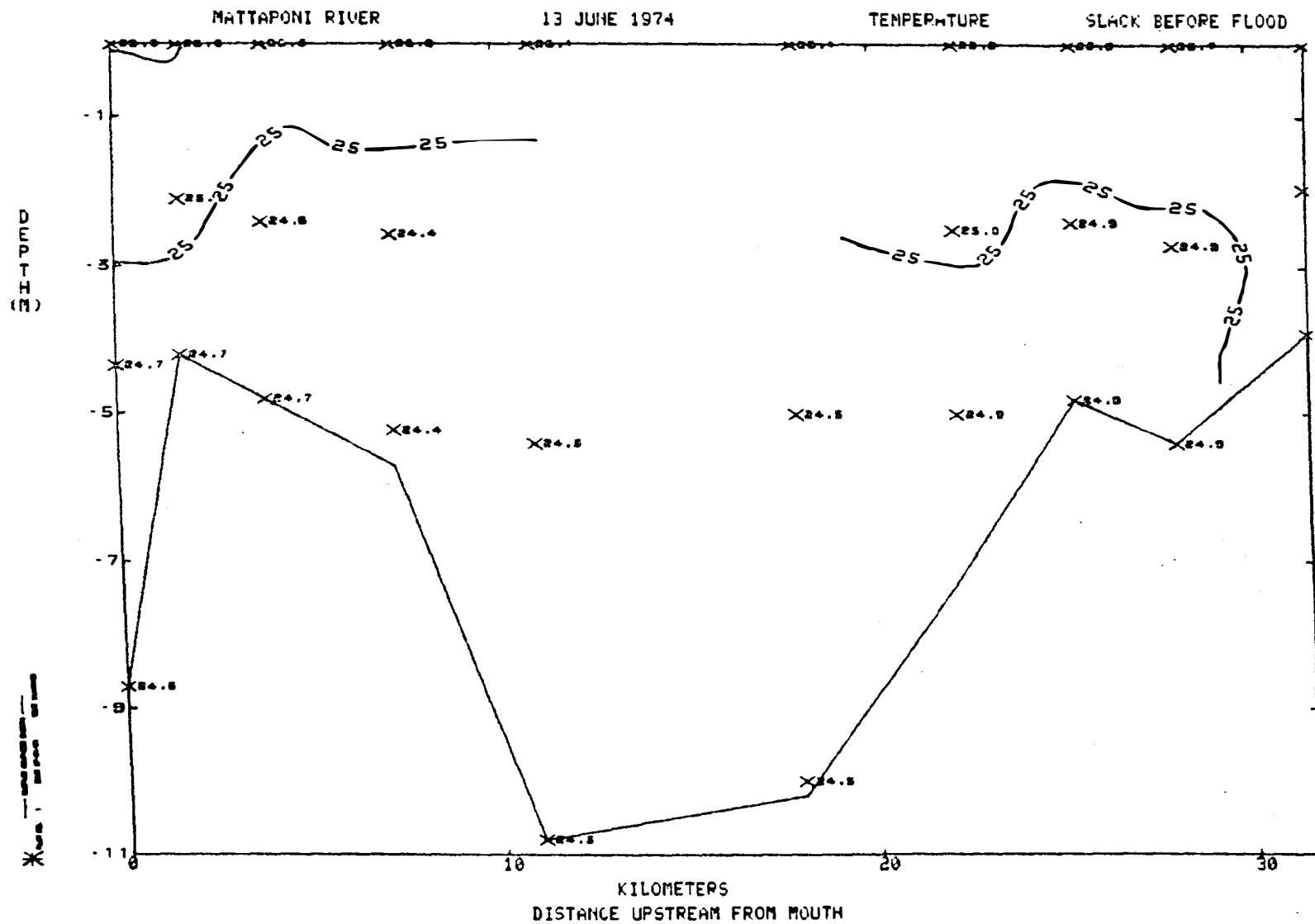


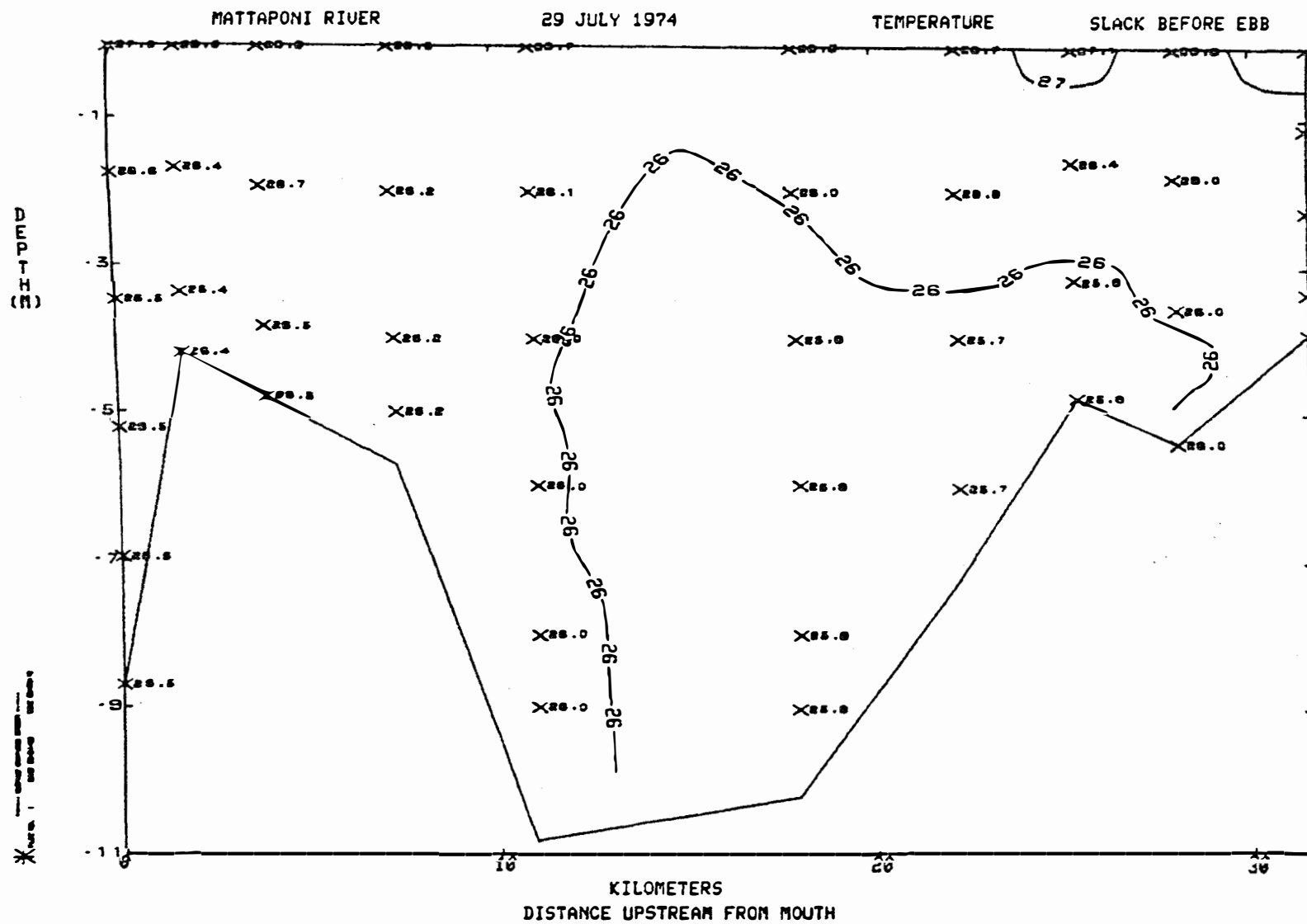


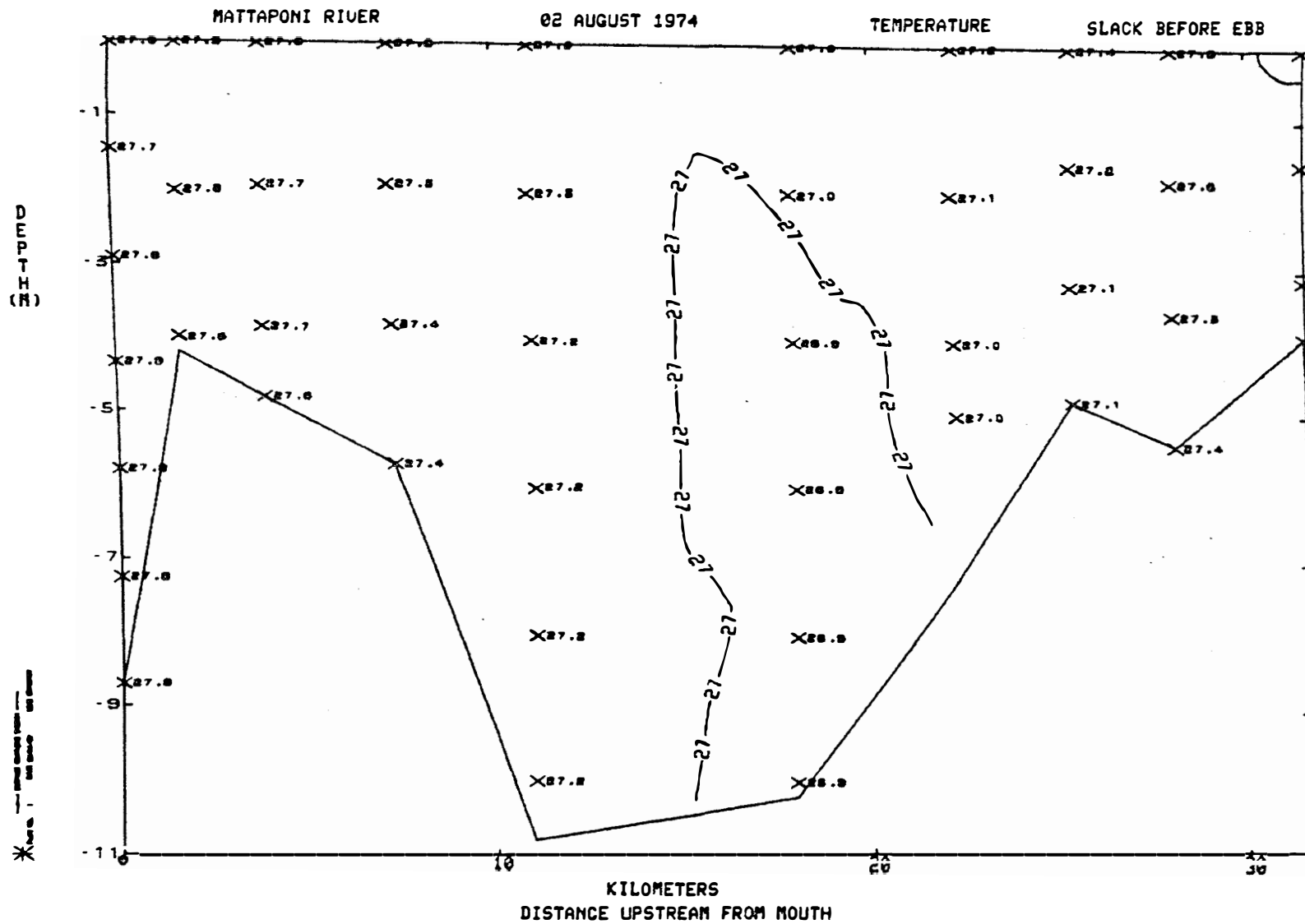


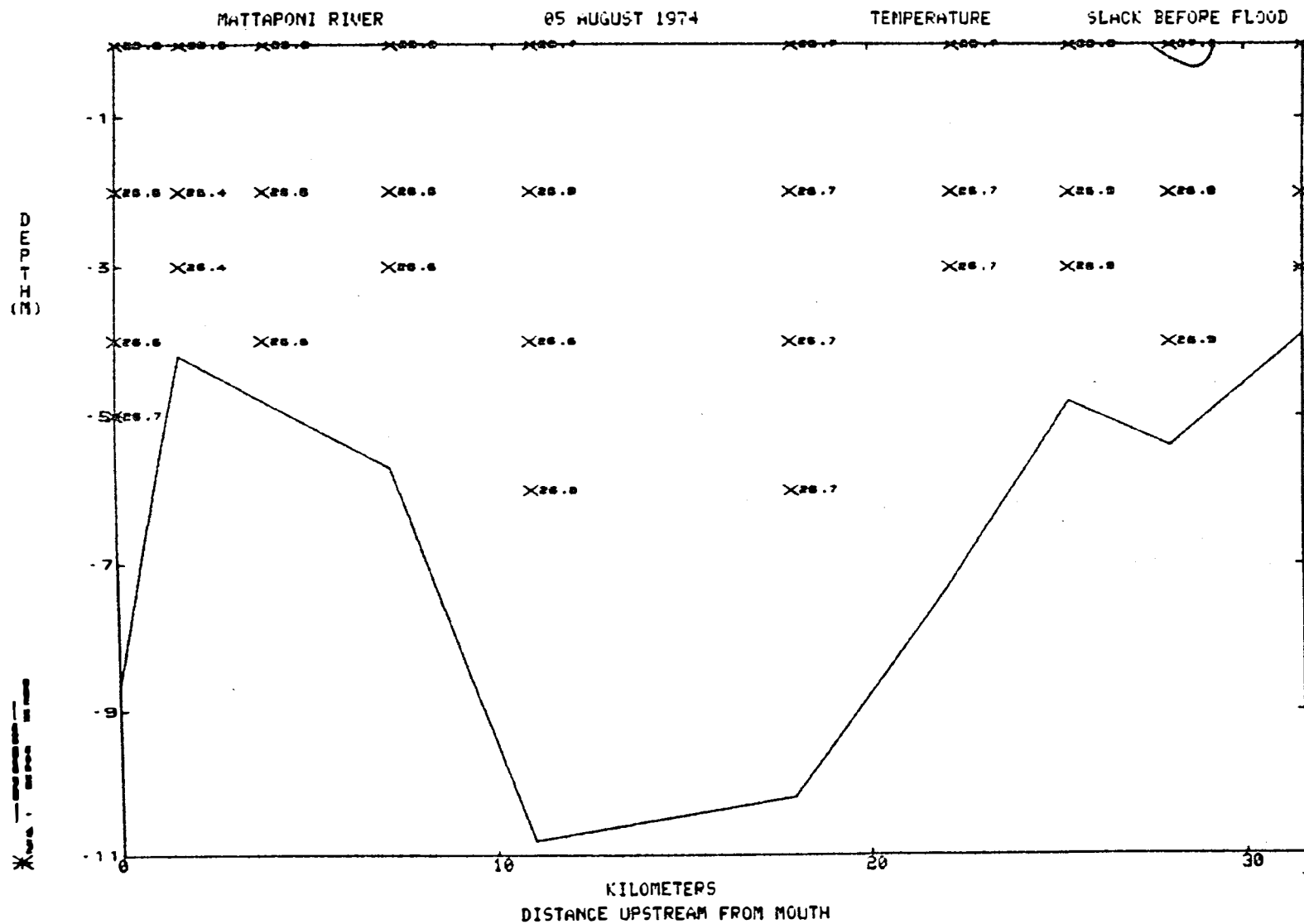


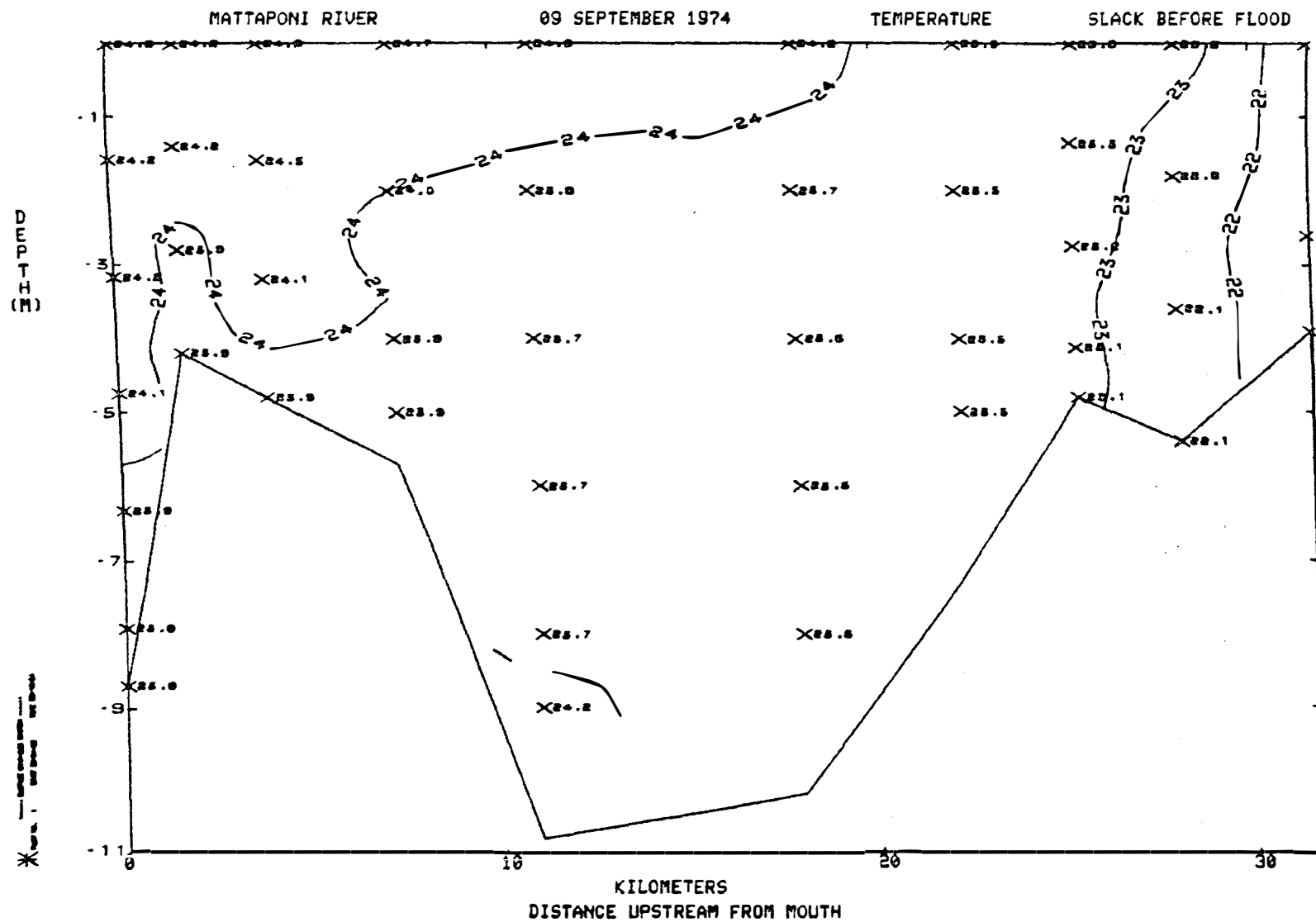


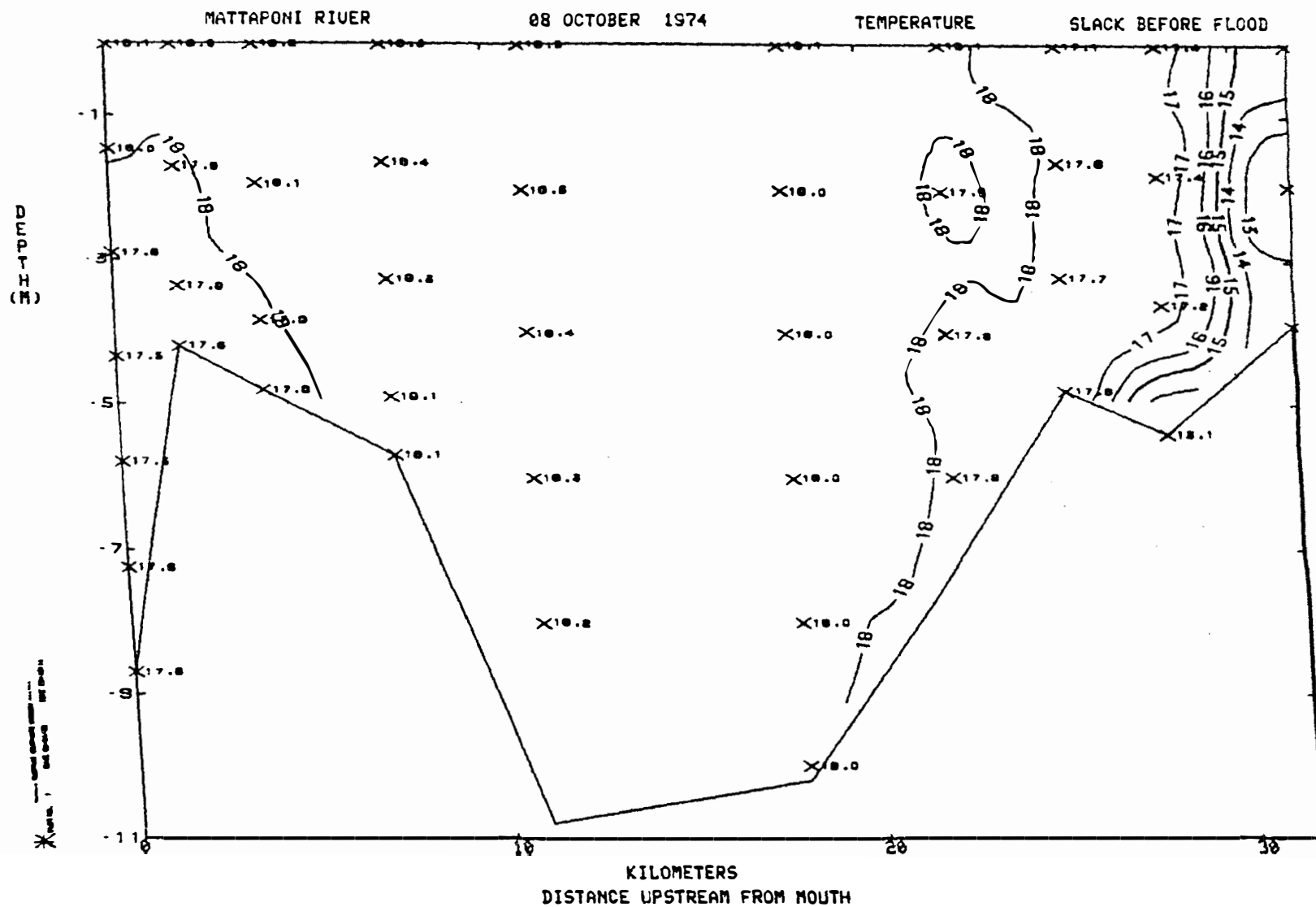


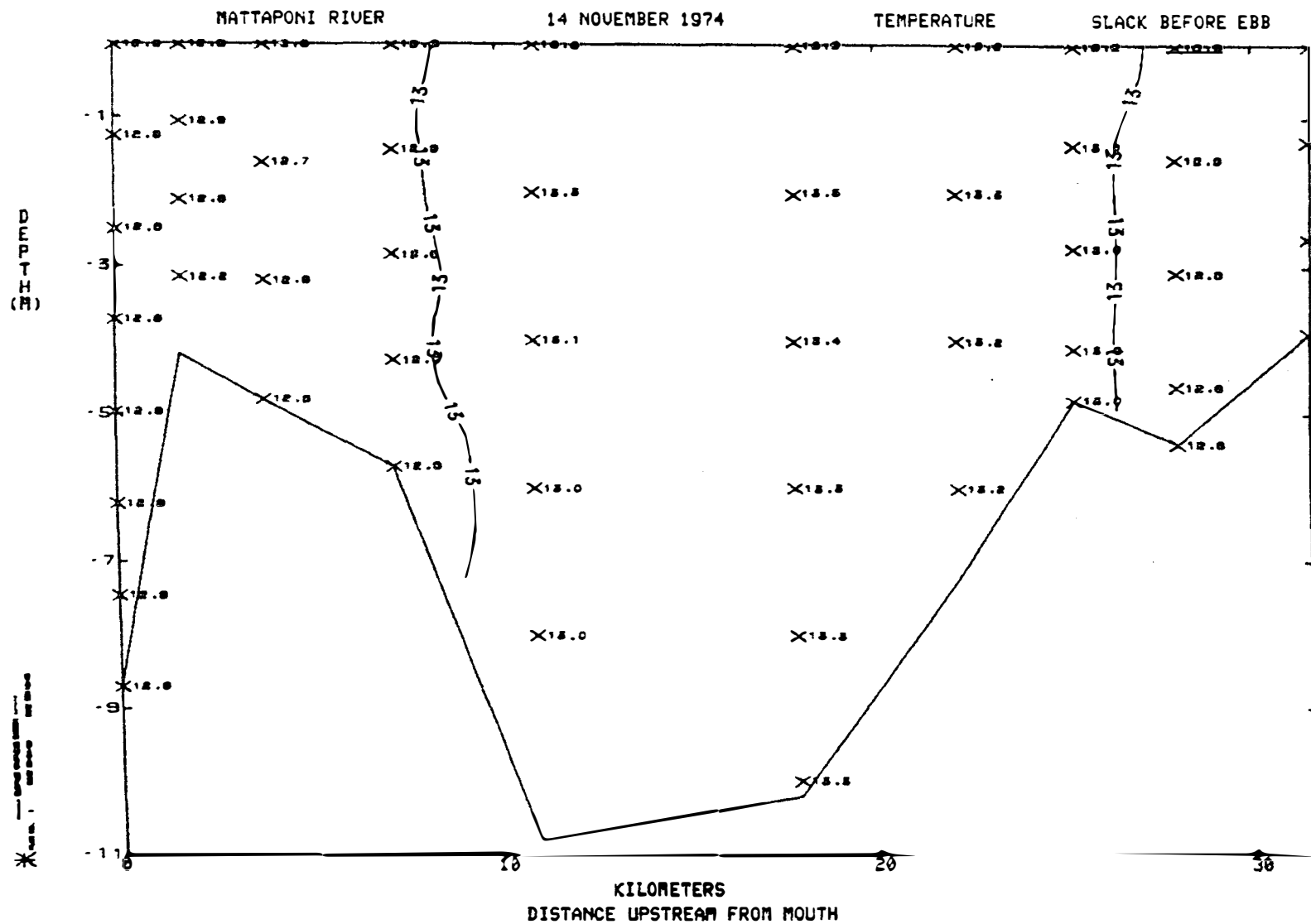


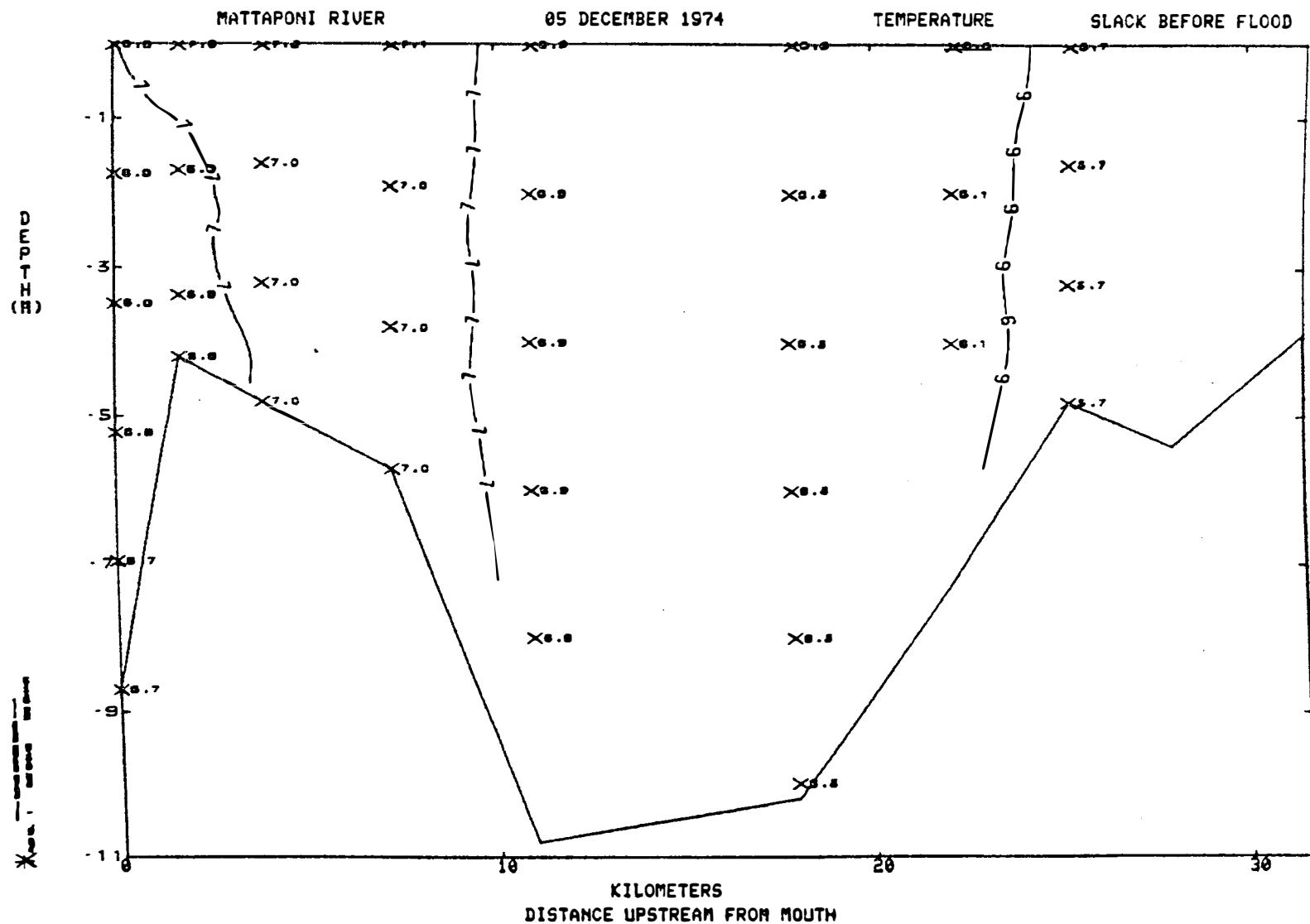


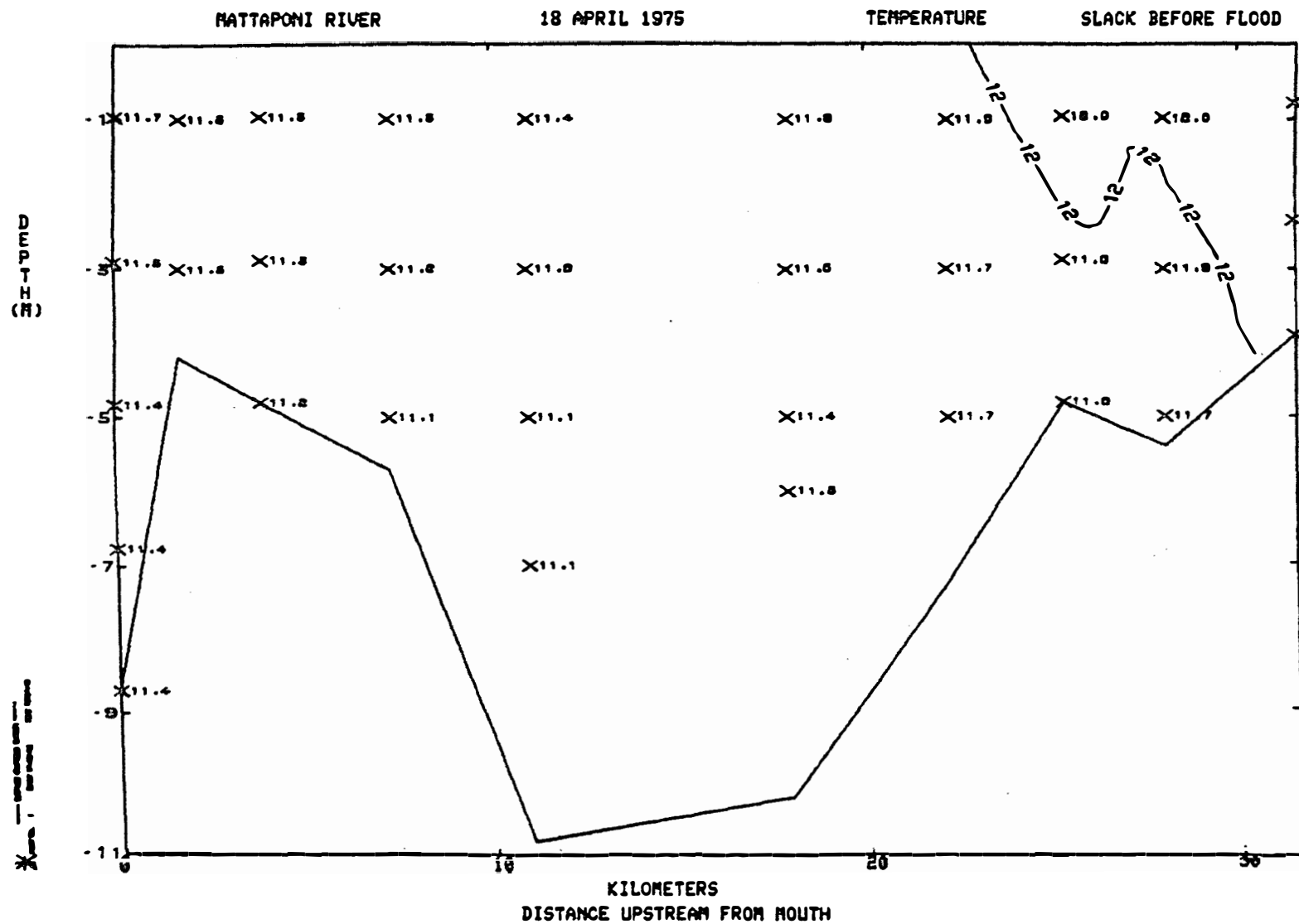


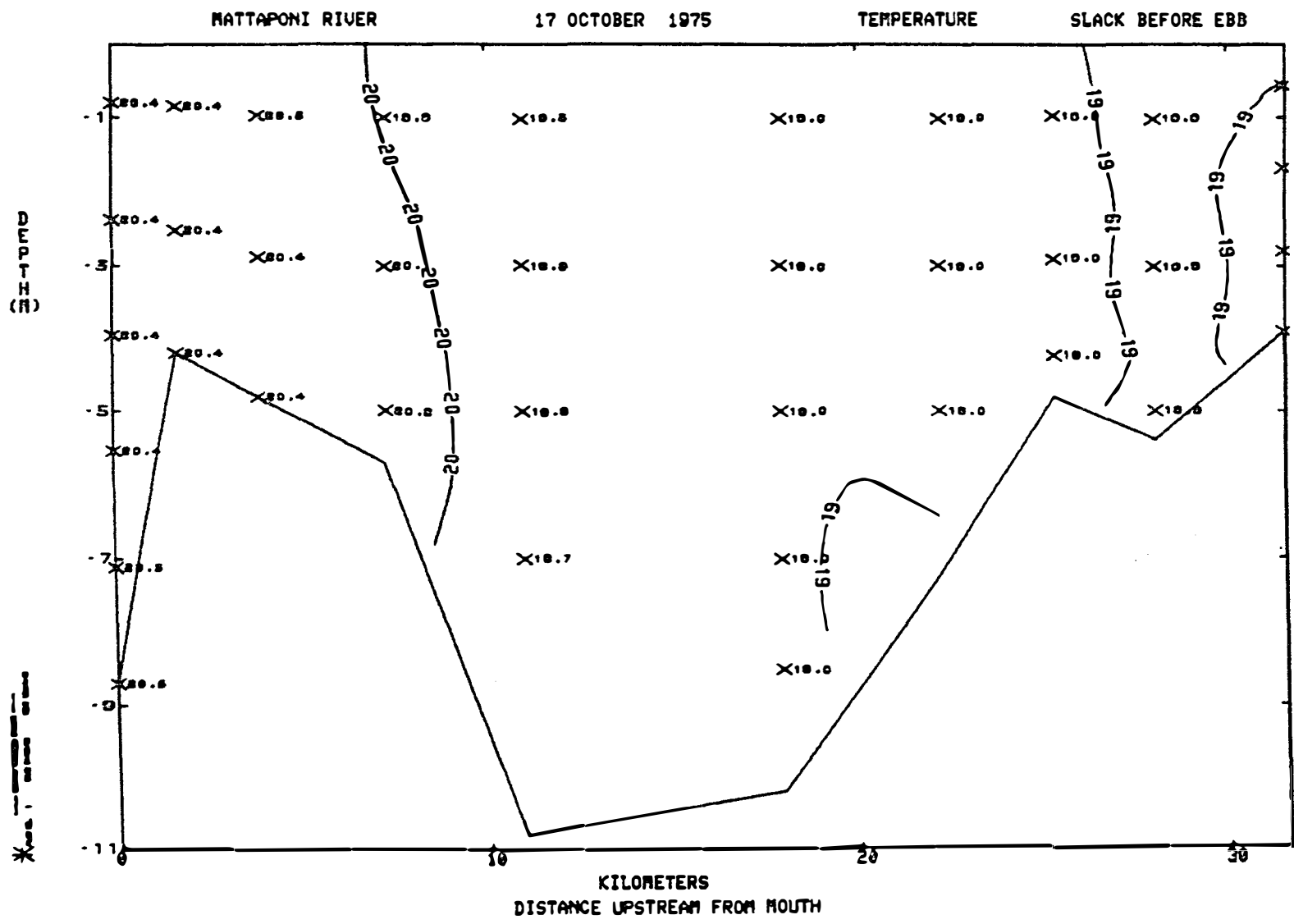










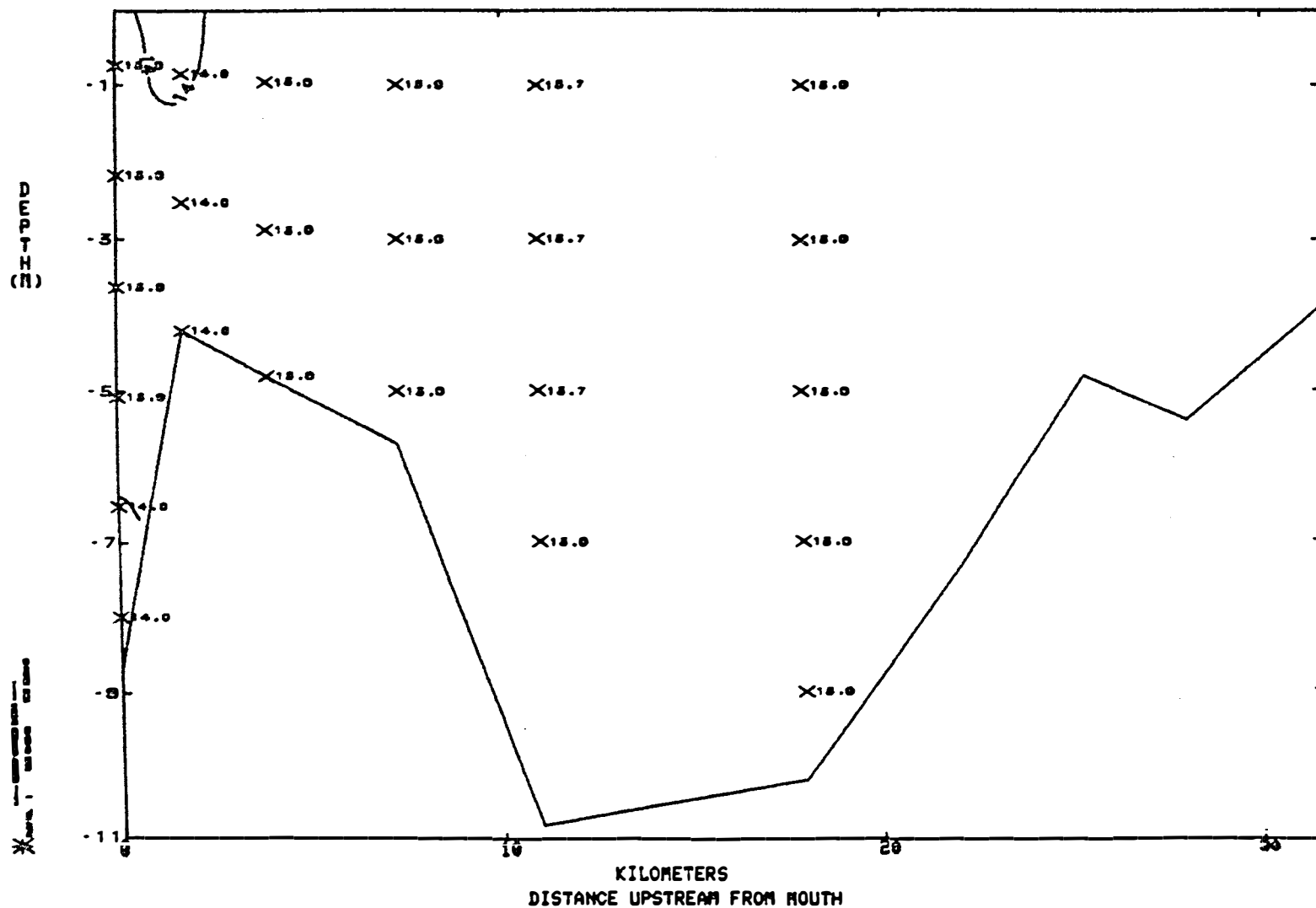


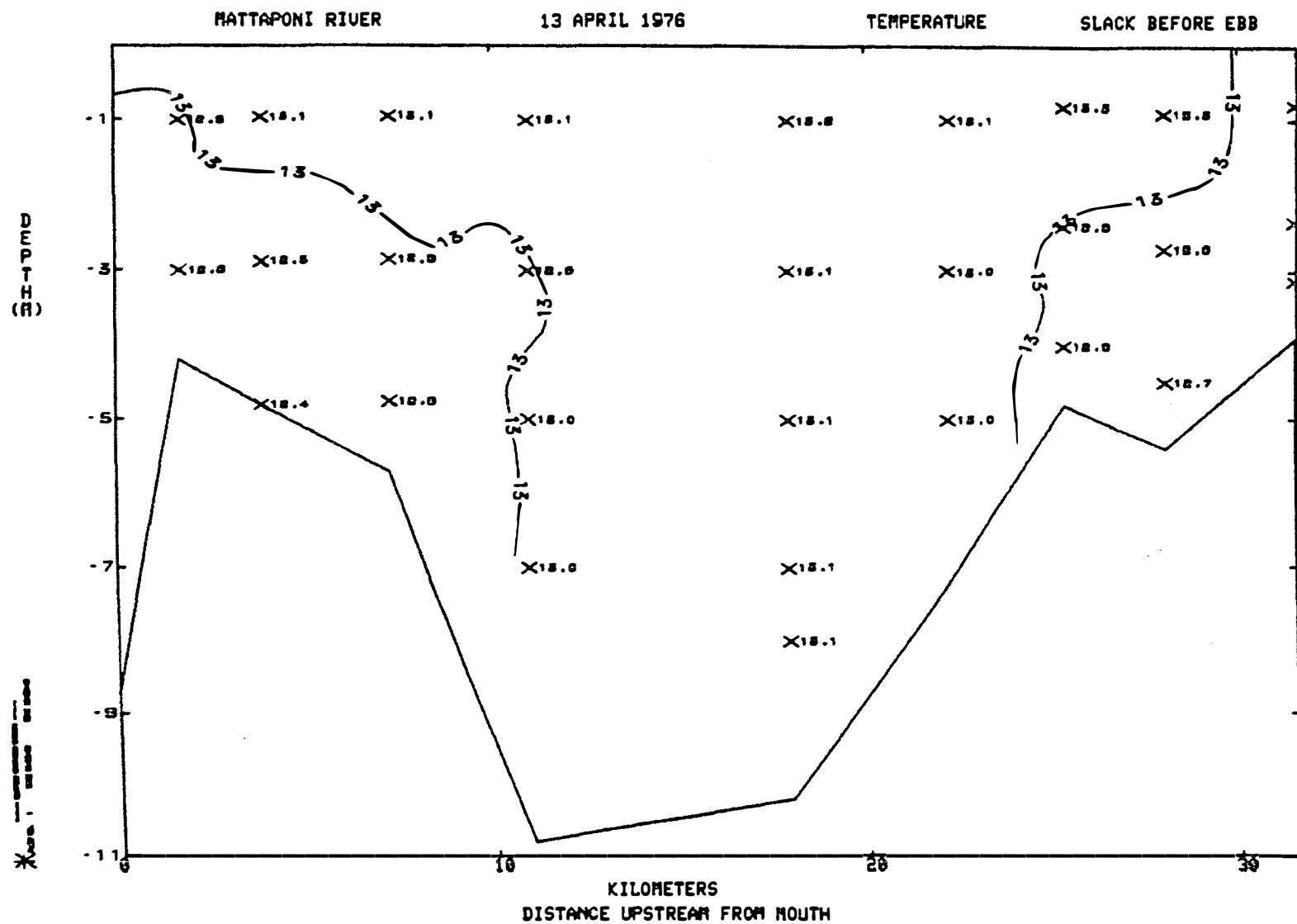
MATTAPONI RIVER

18 NOVEMBER 1975

TEMPERATURE

SLACK BEFORE EBB



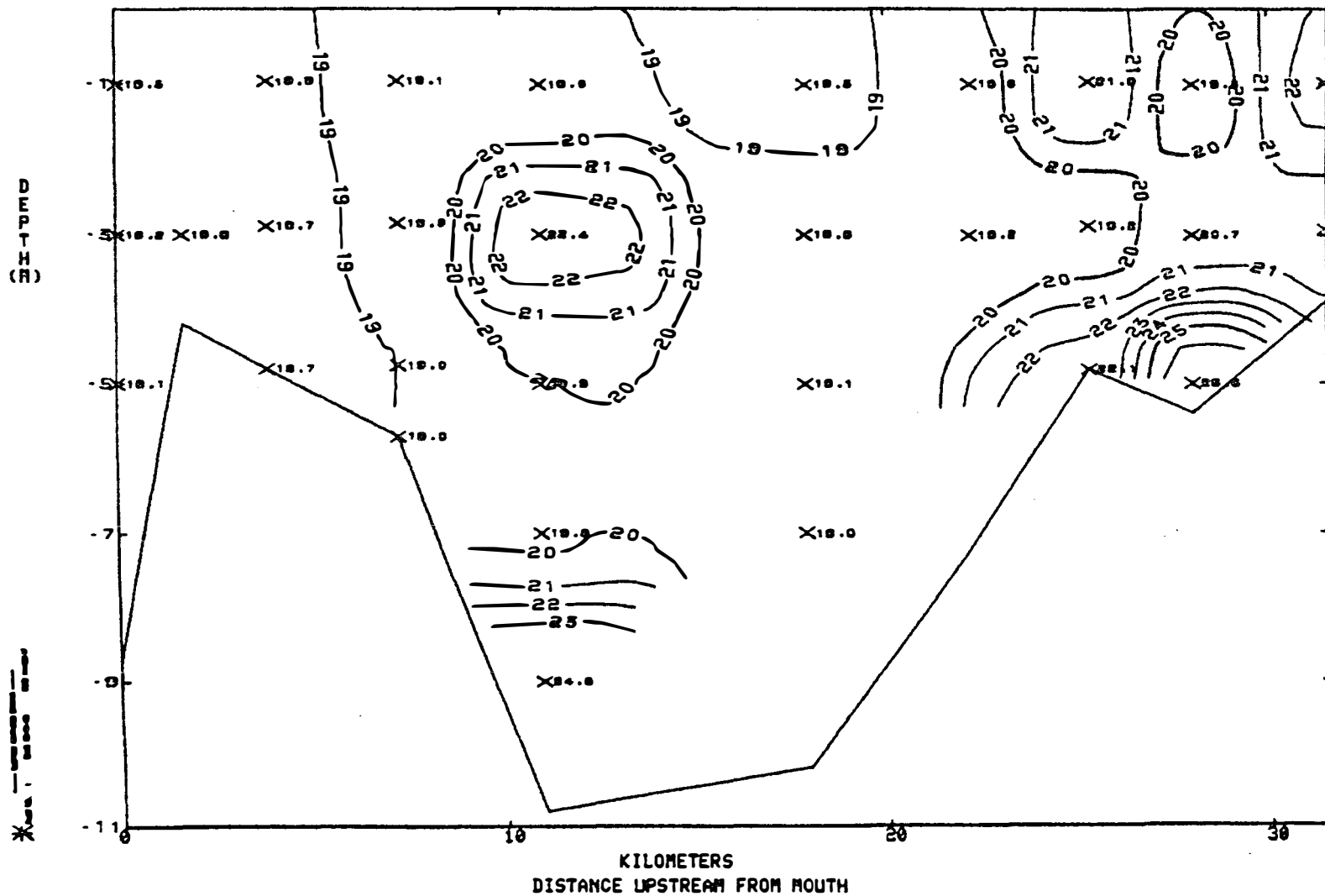


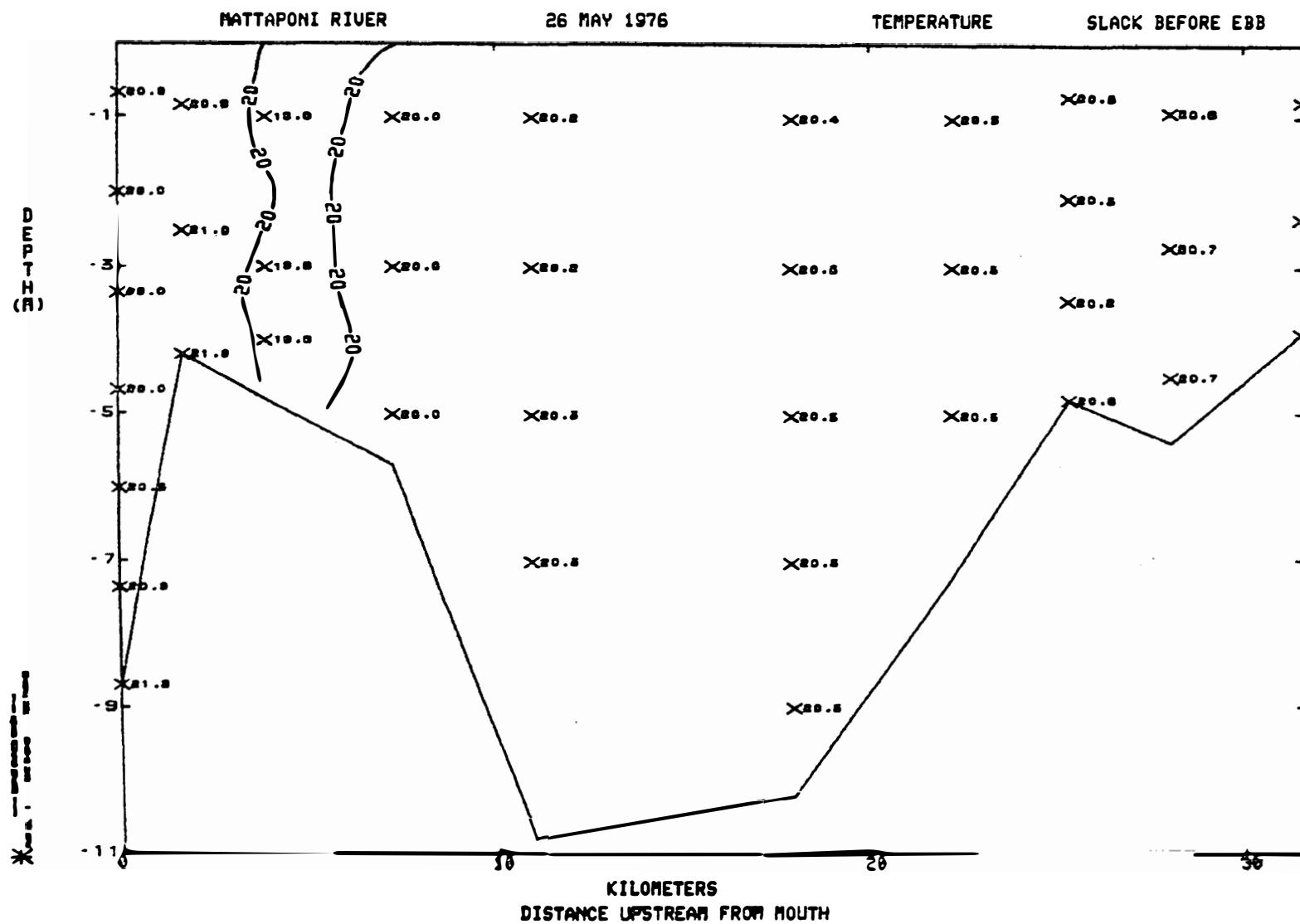
MATTAPONI RIVER

05 MAY 1976

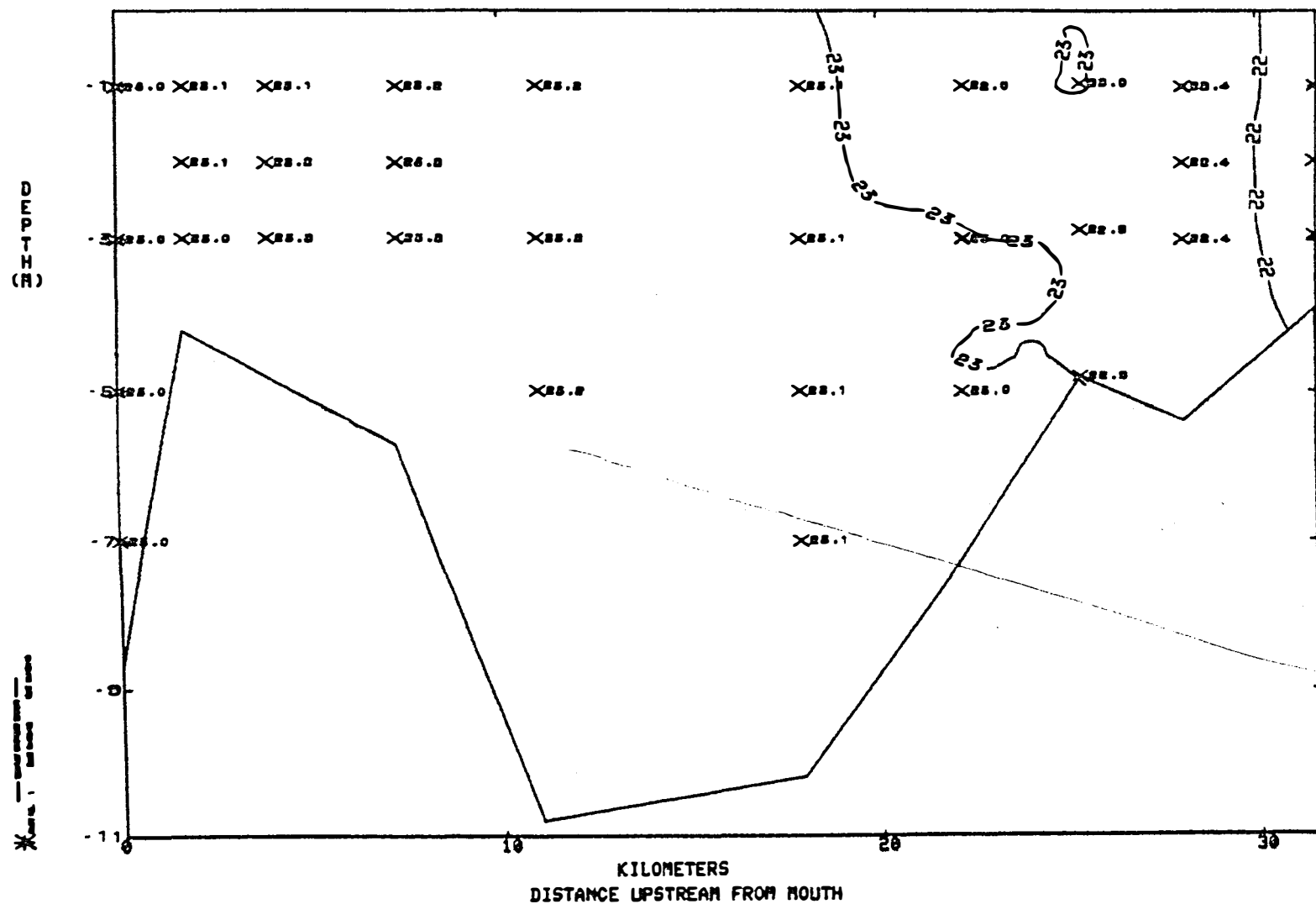
TEMPERATURE

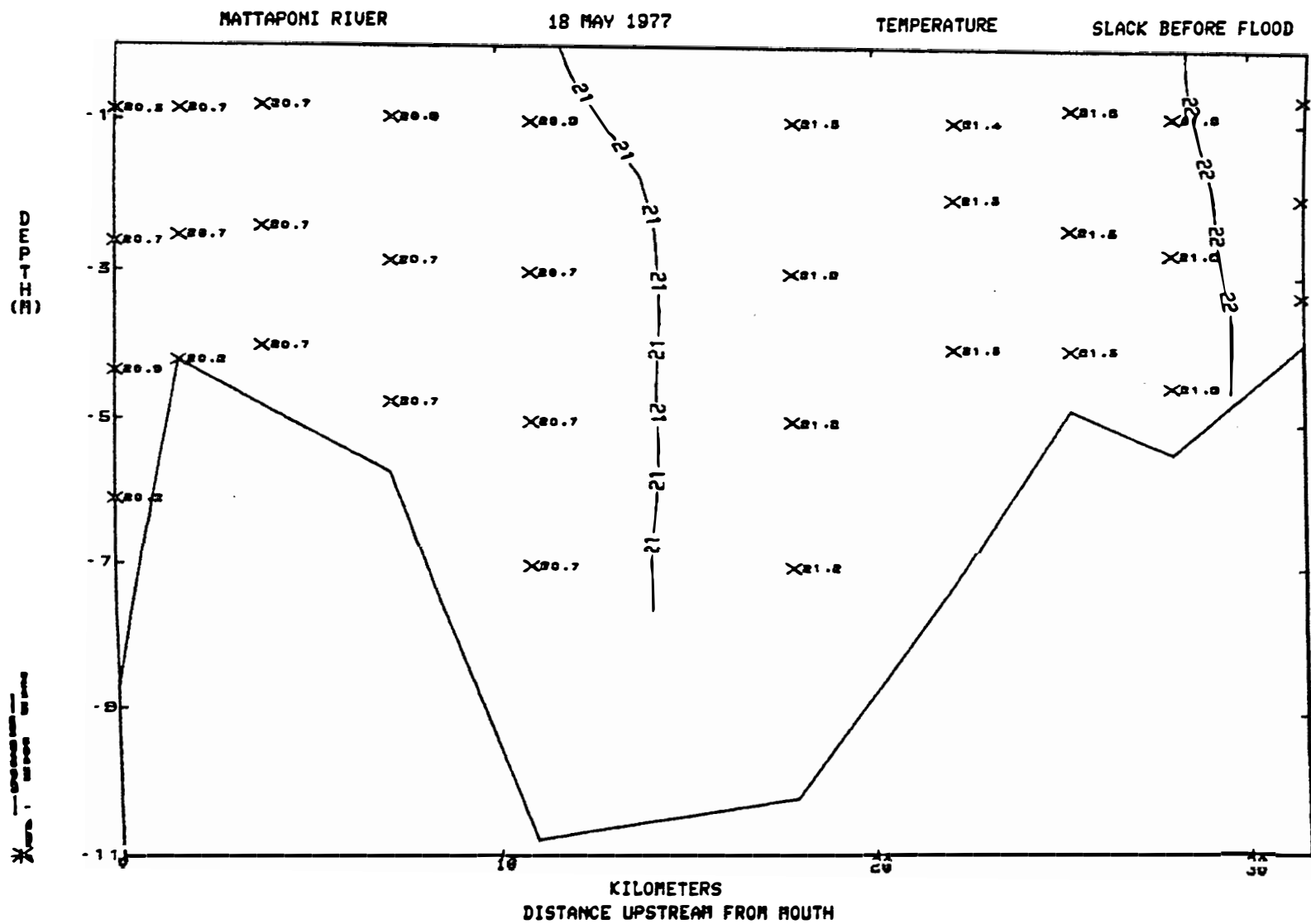
SLACK BEFORE FLOOD

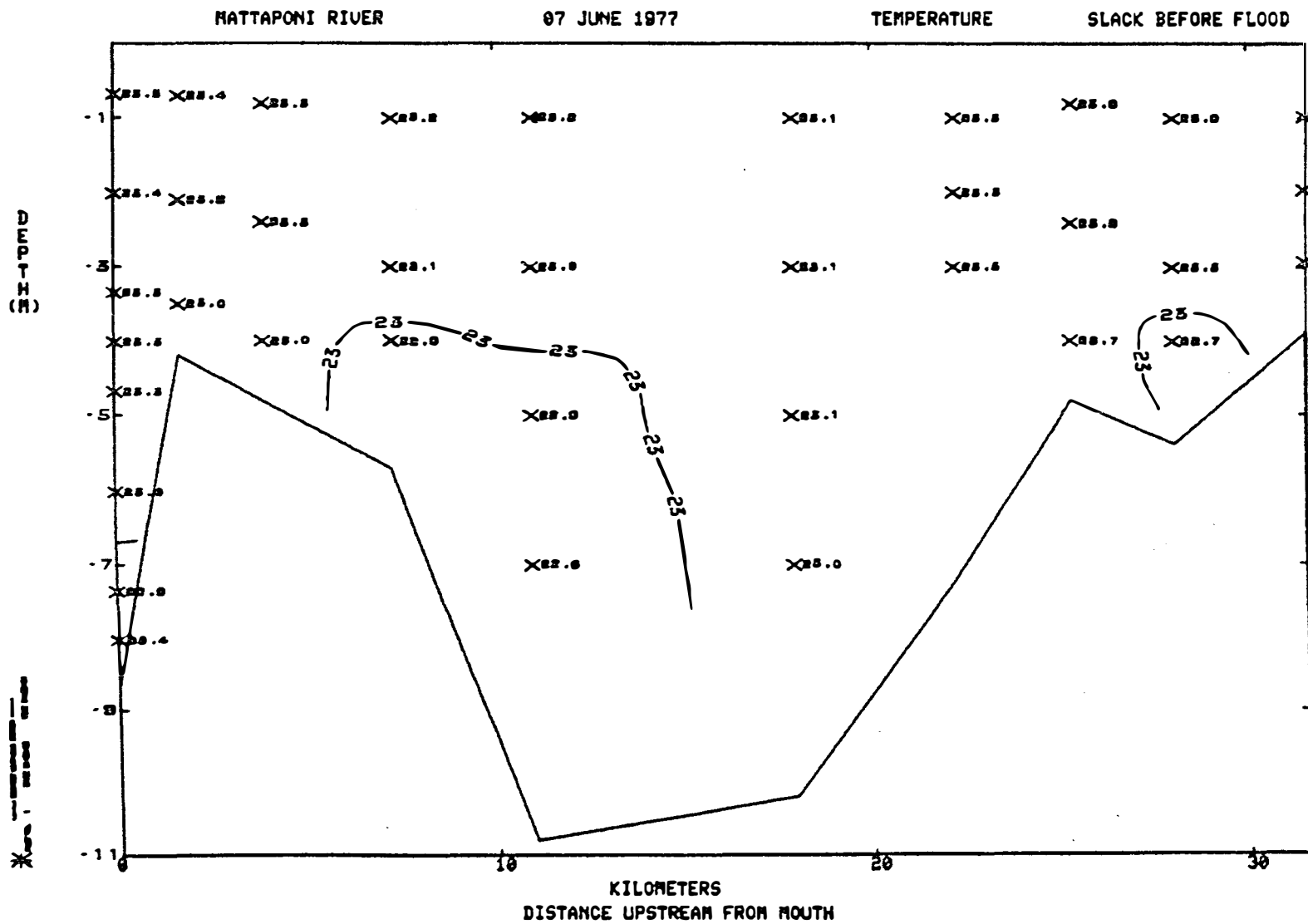


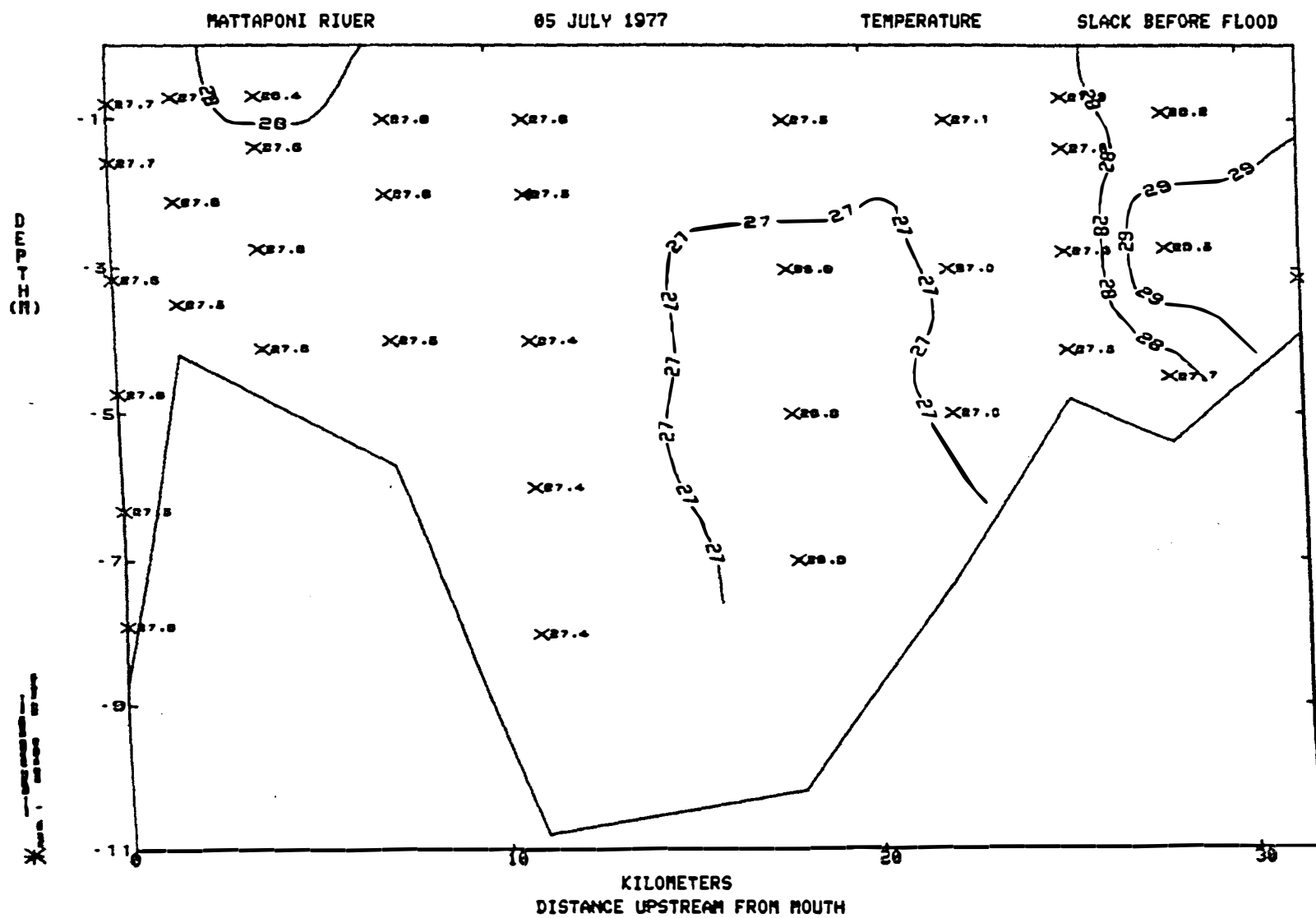


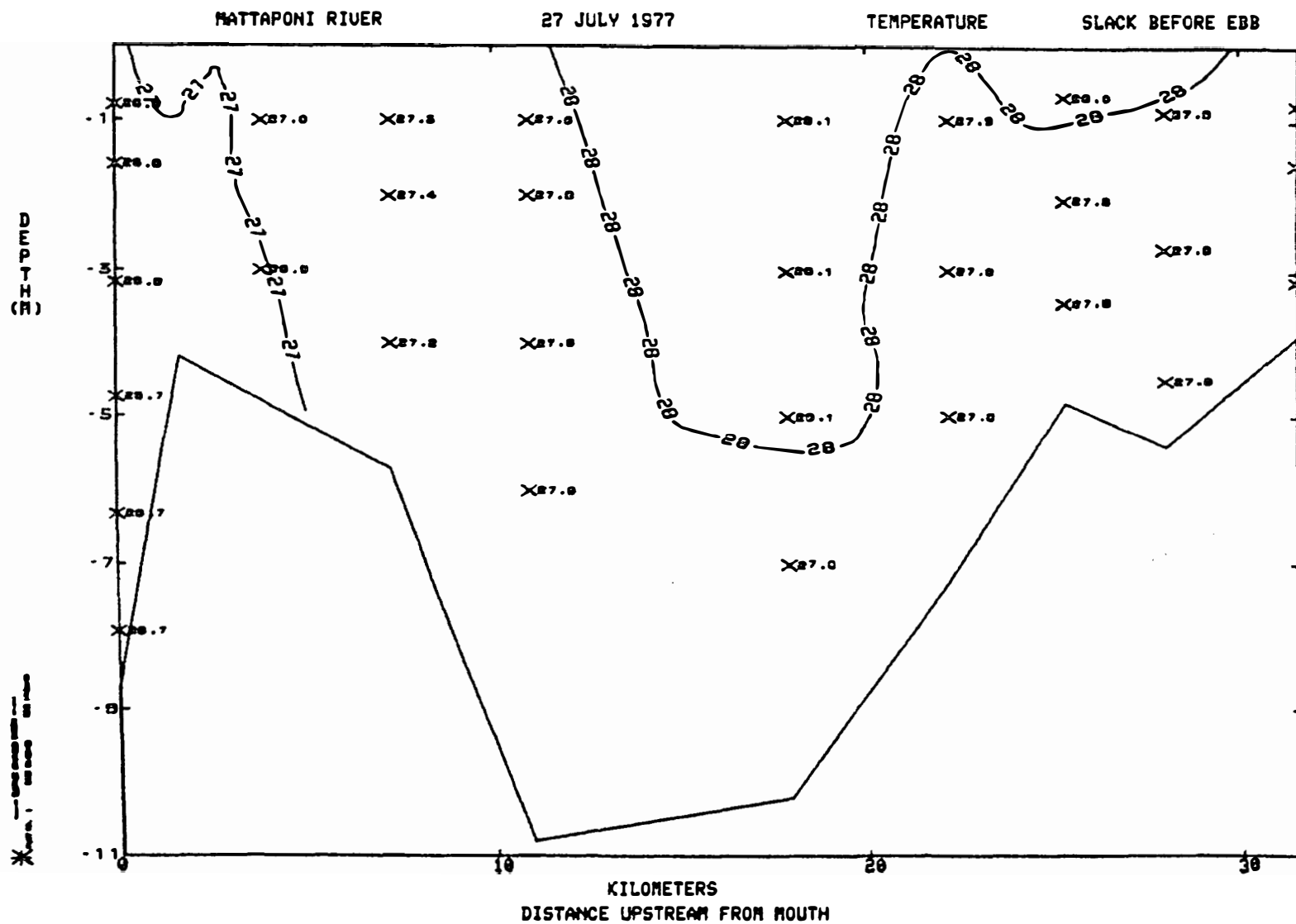
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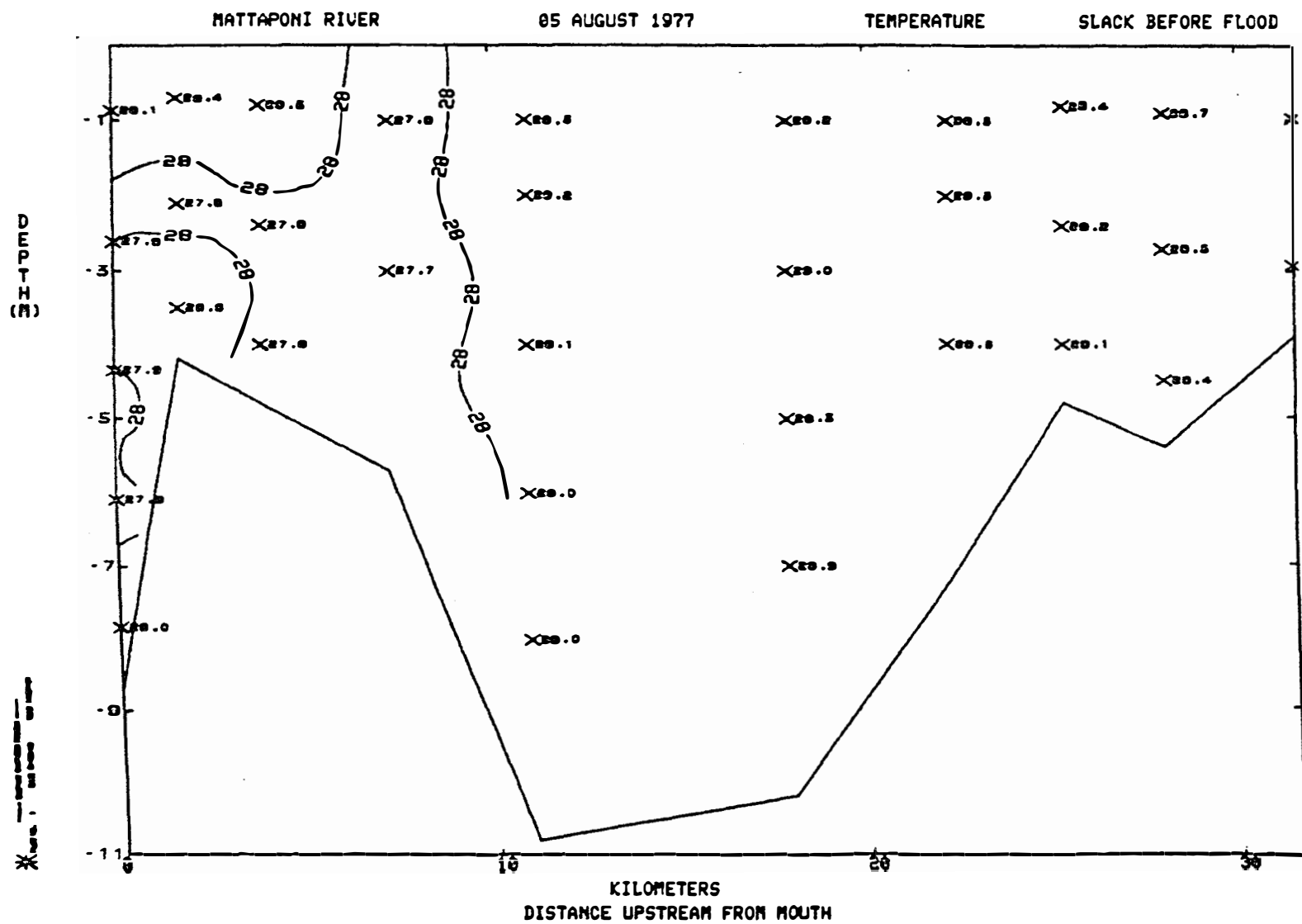


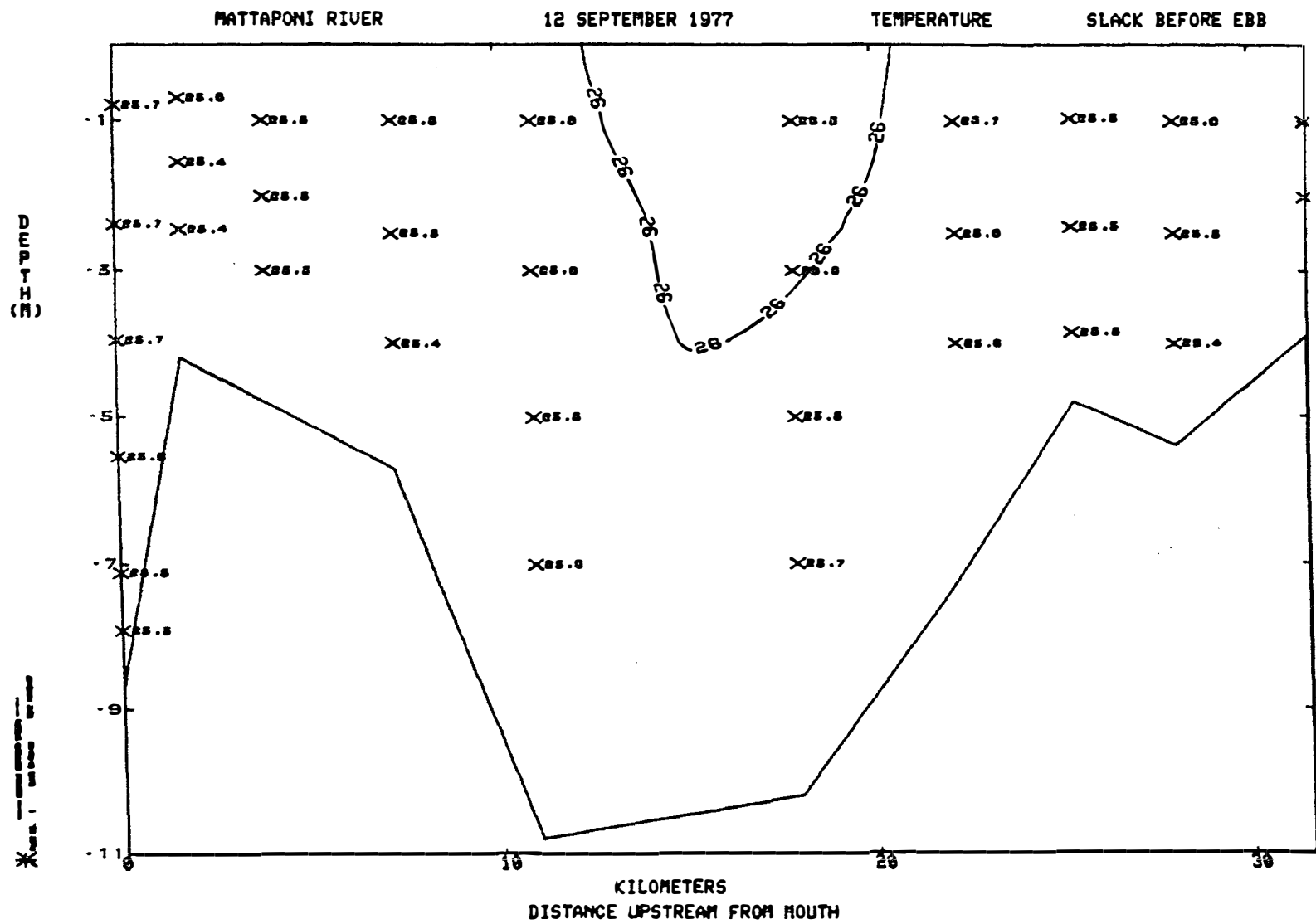


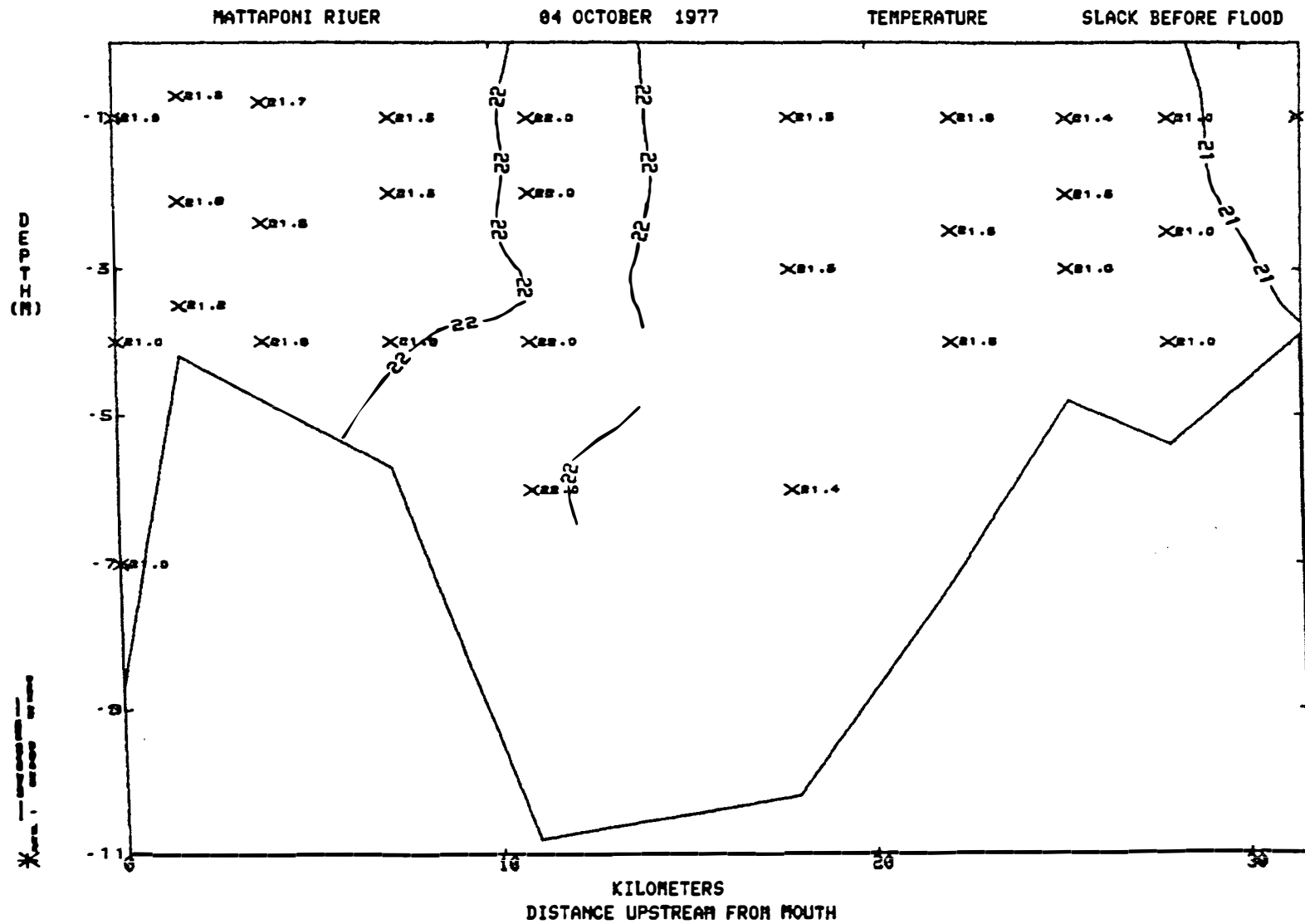


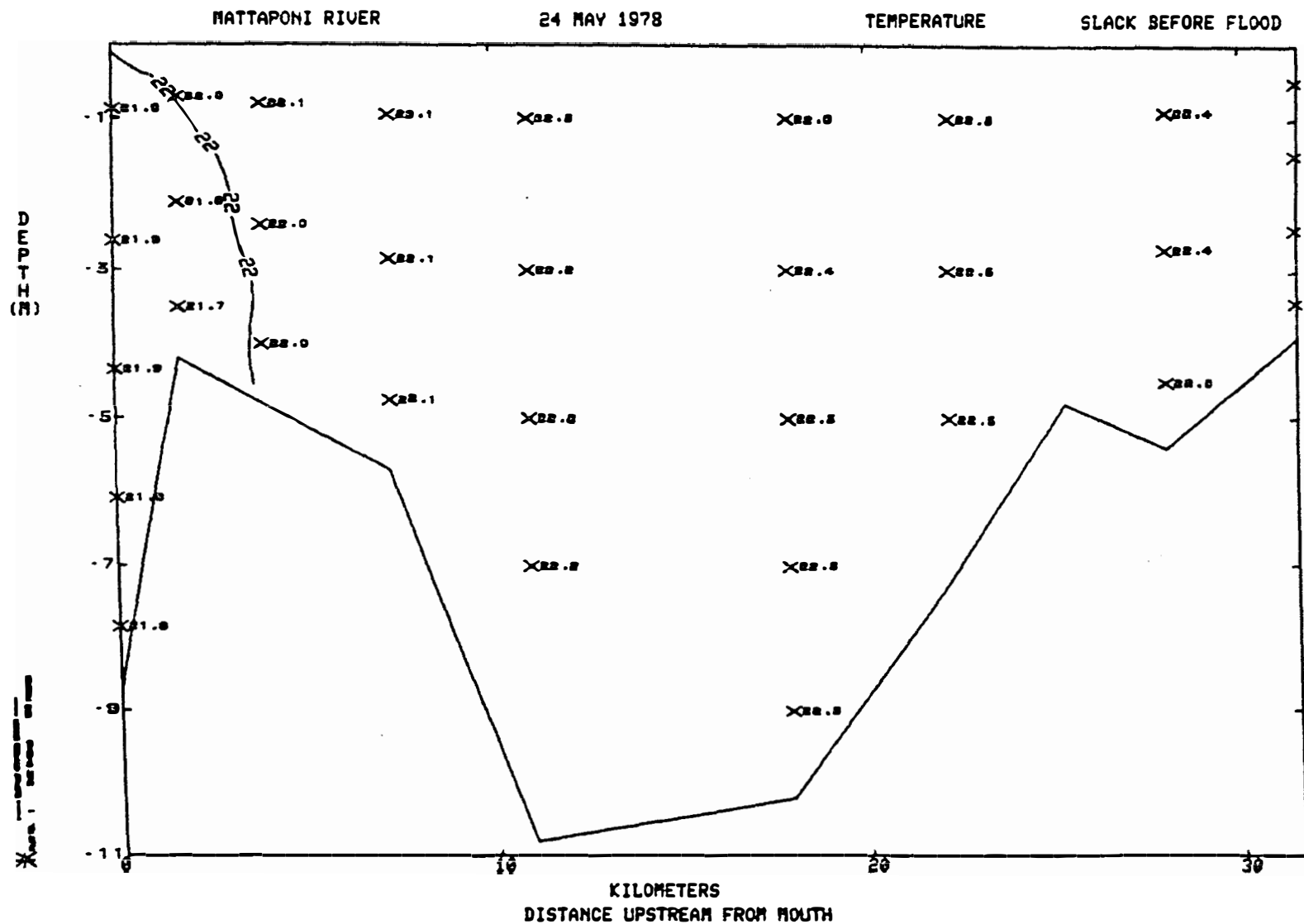


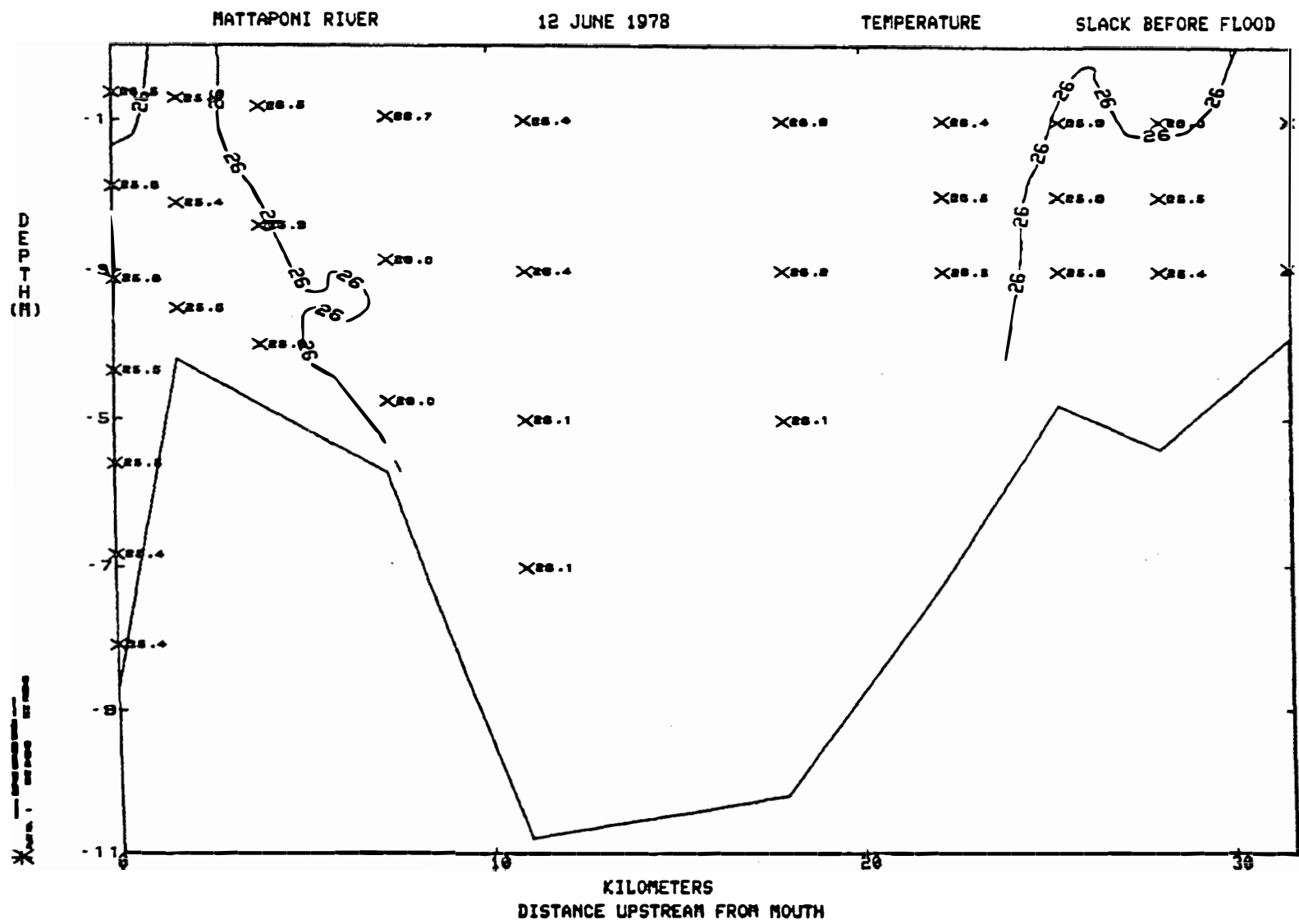




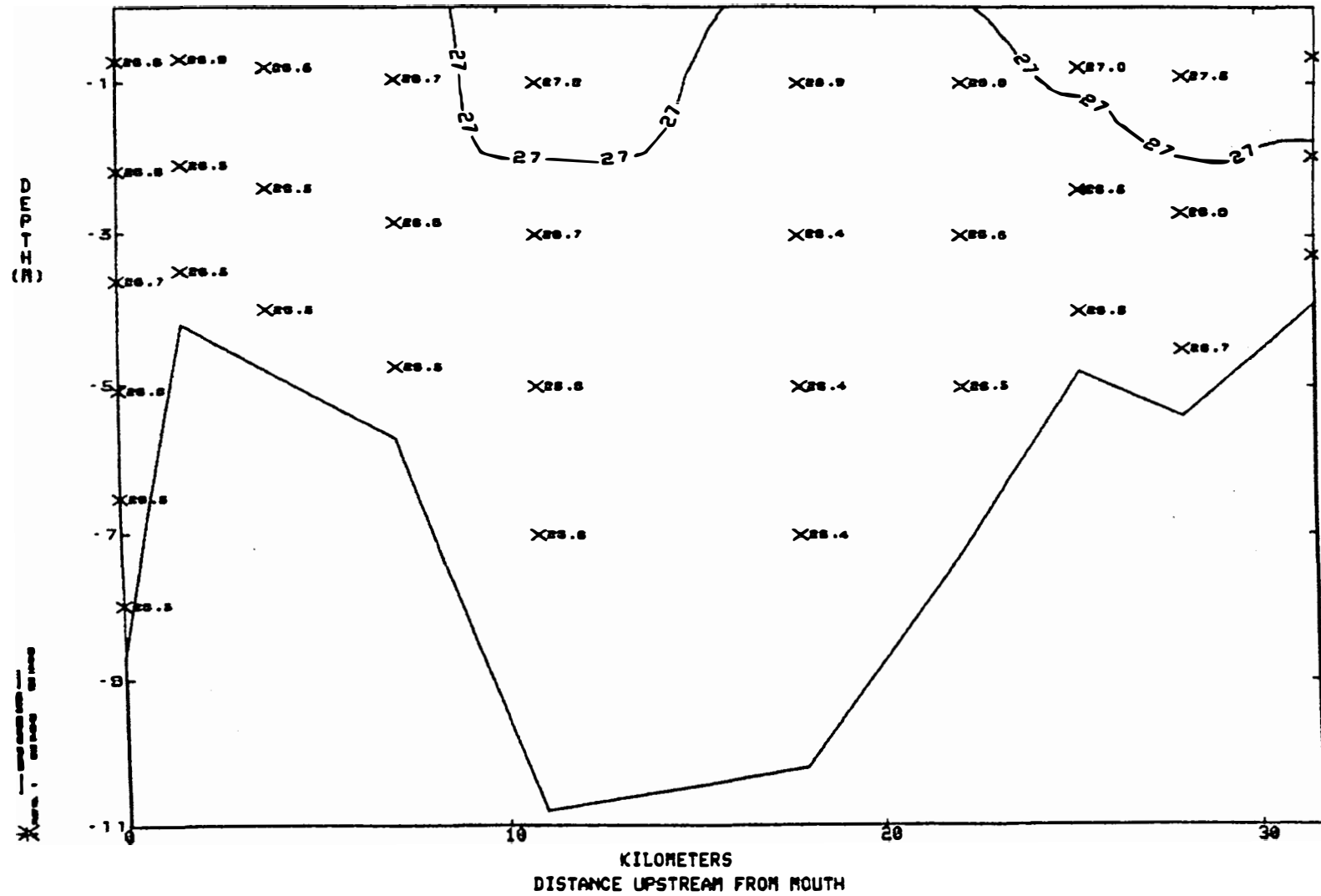








SLACK BEFORE EBB

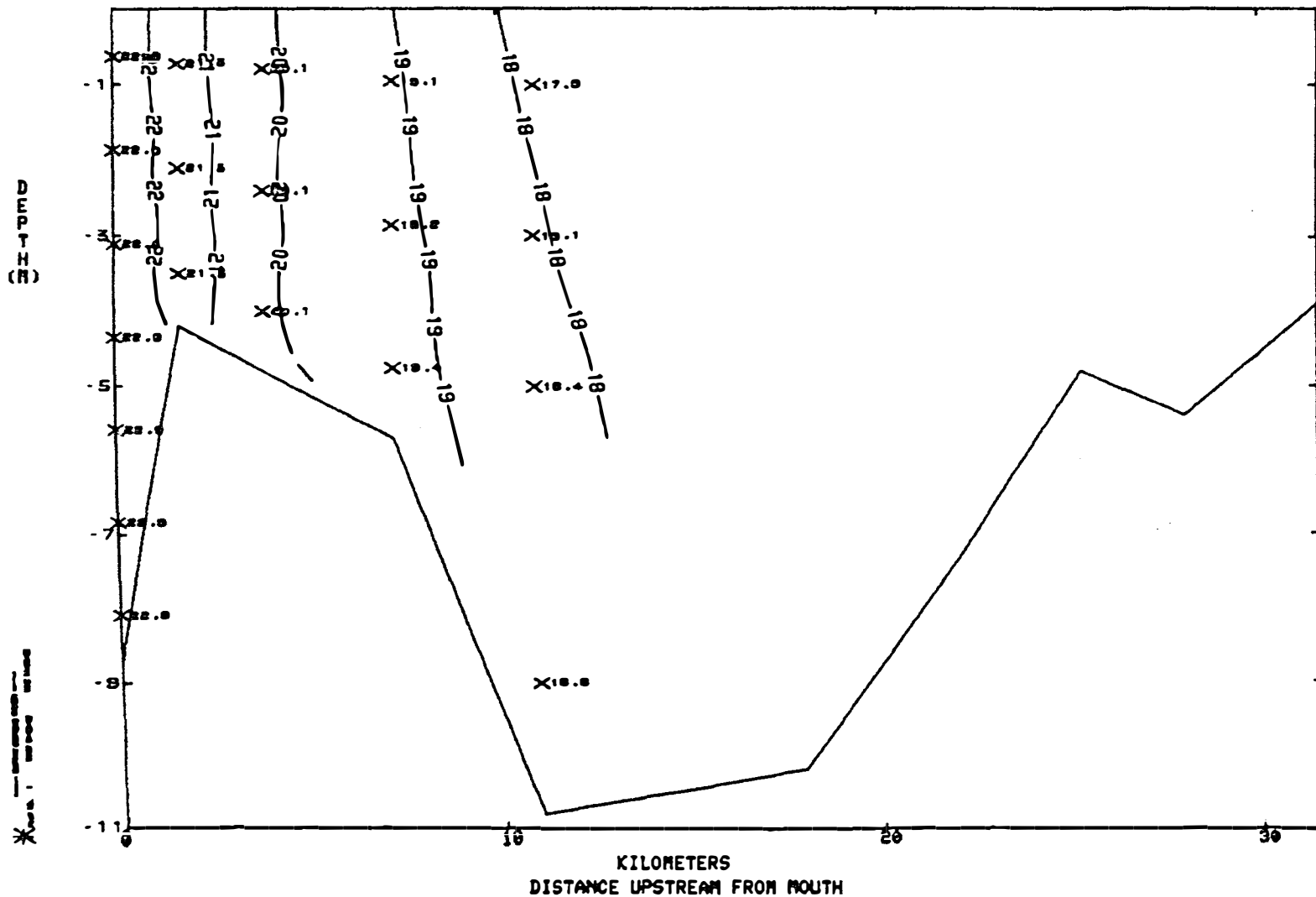


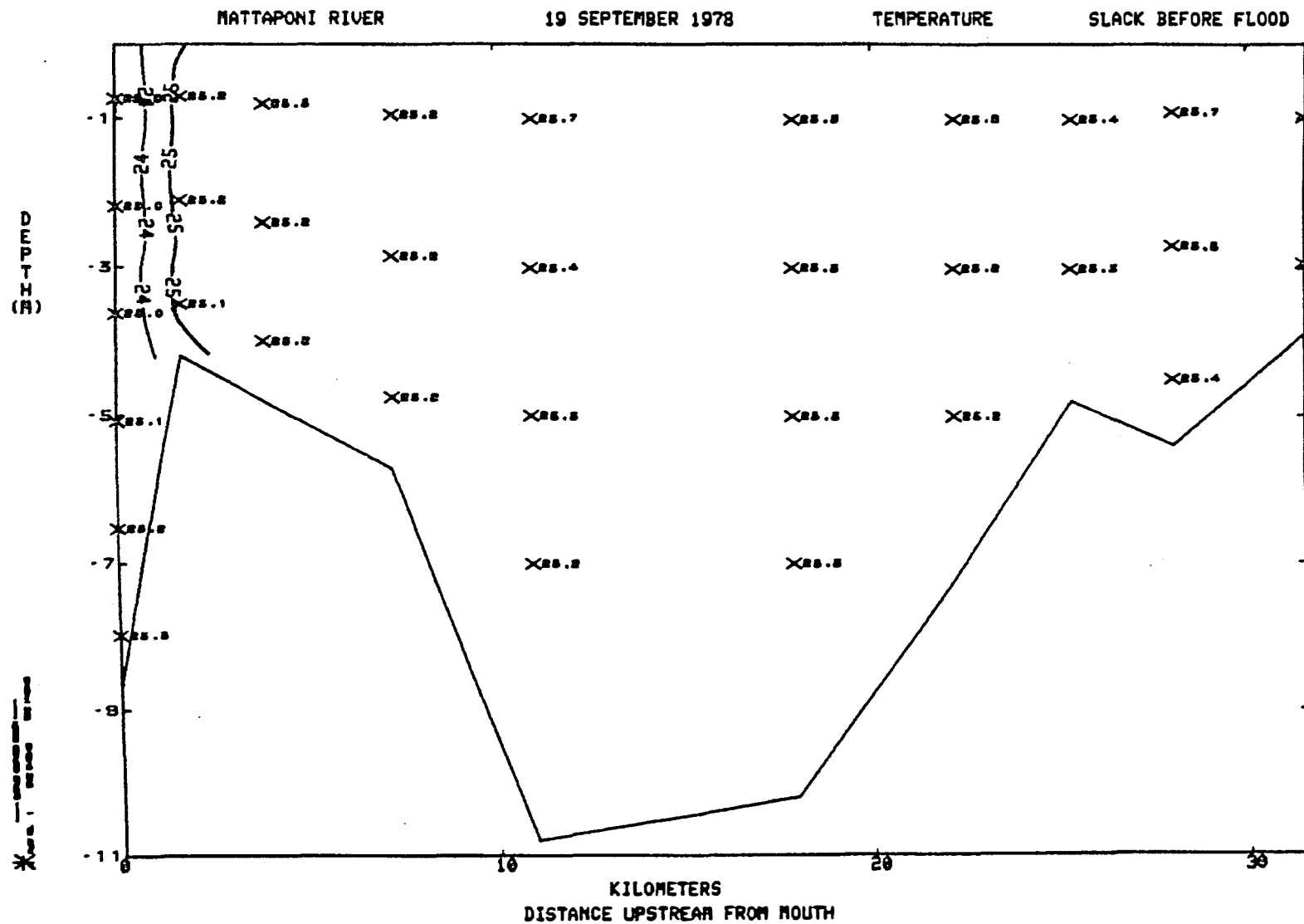
MATTAPONI RIVER

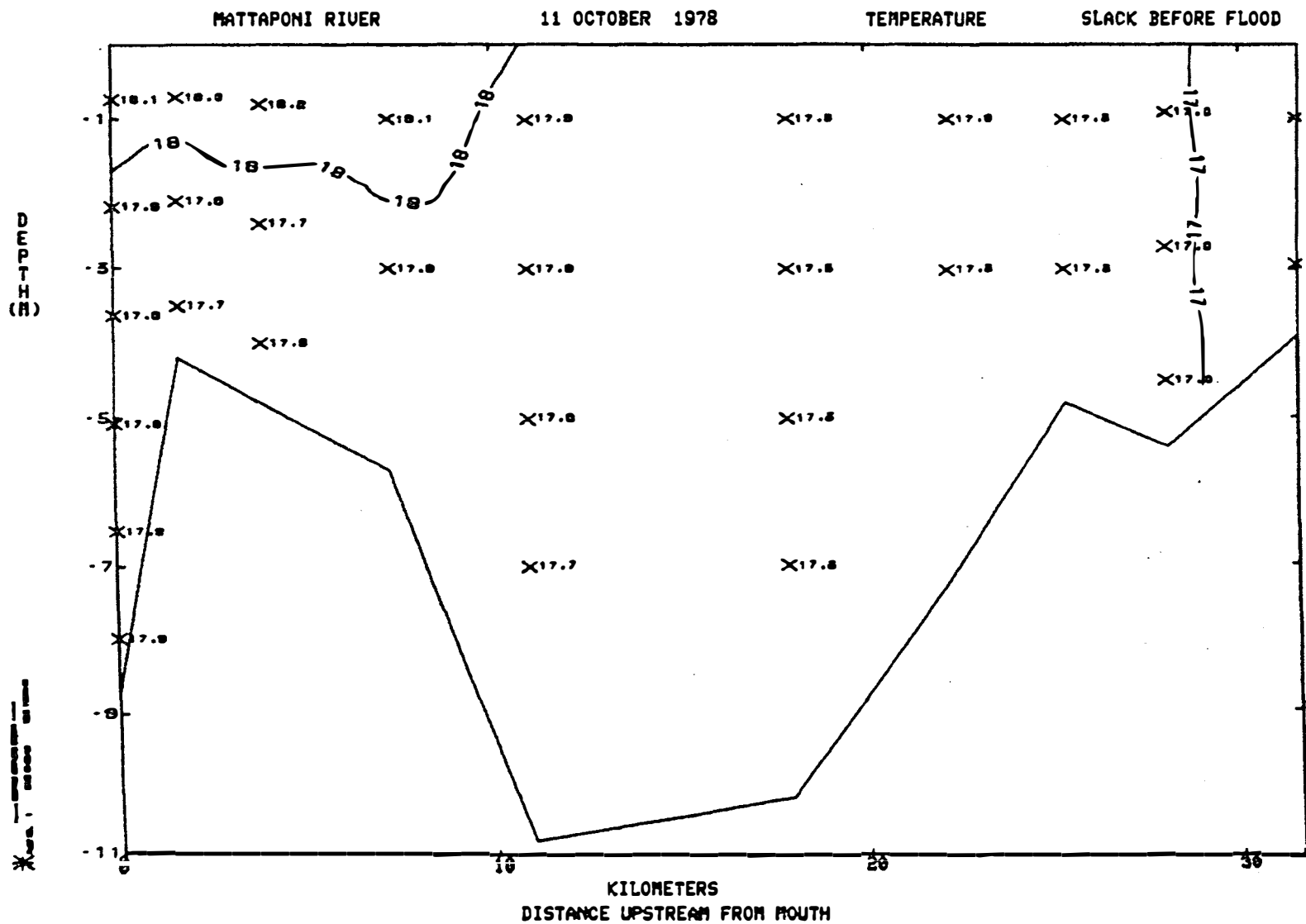
21 AUGUST 1978

TEMPERATURE

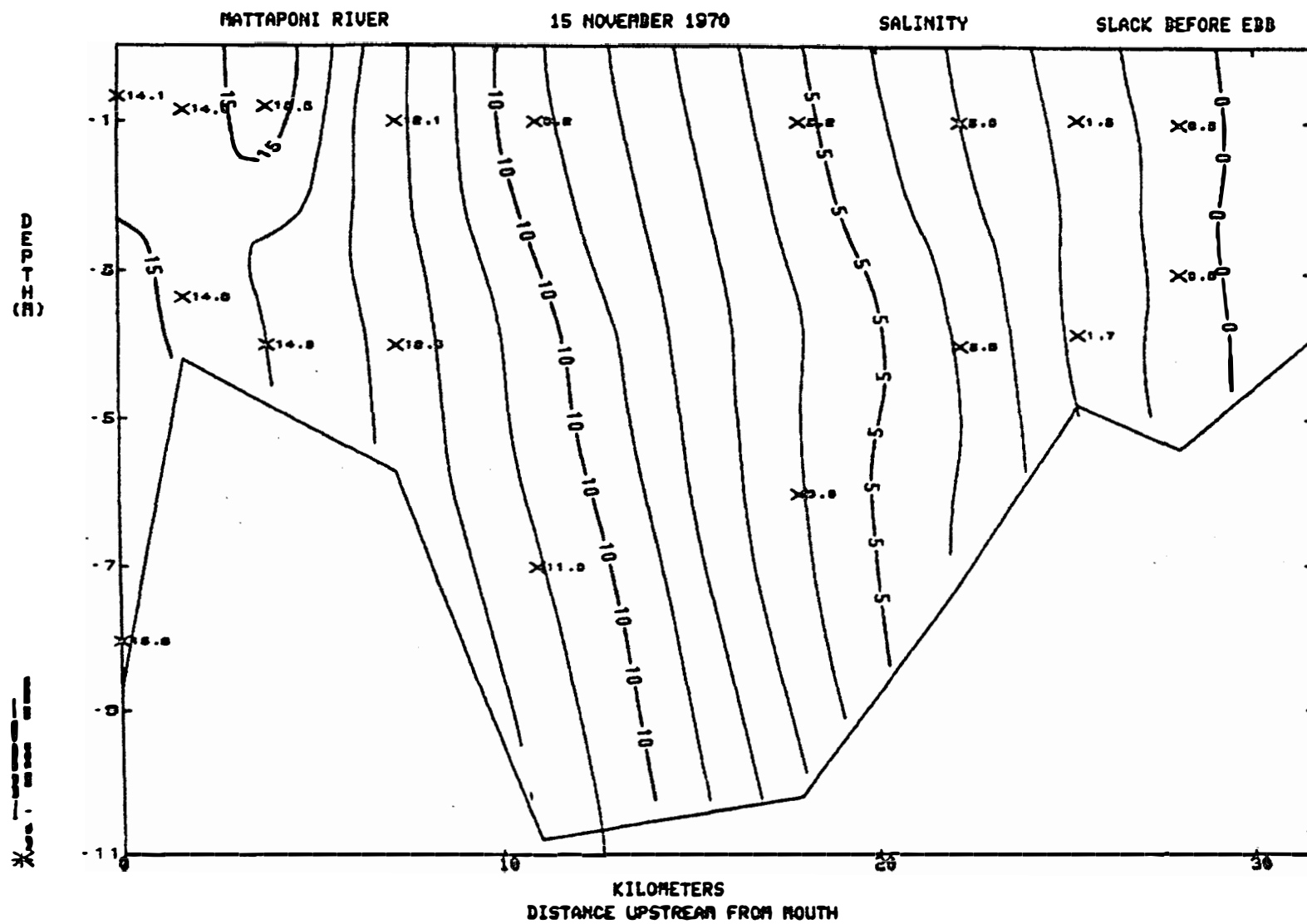
SLACK BEFORE FLOOD

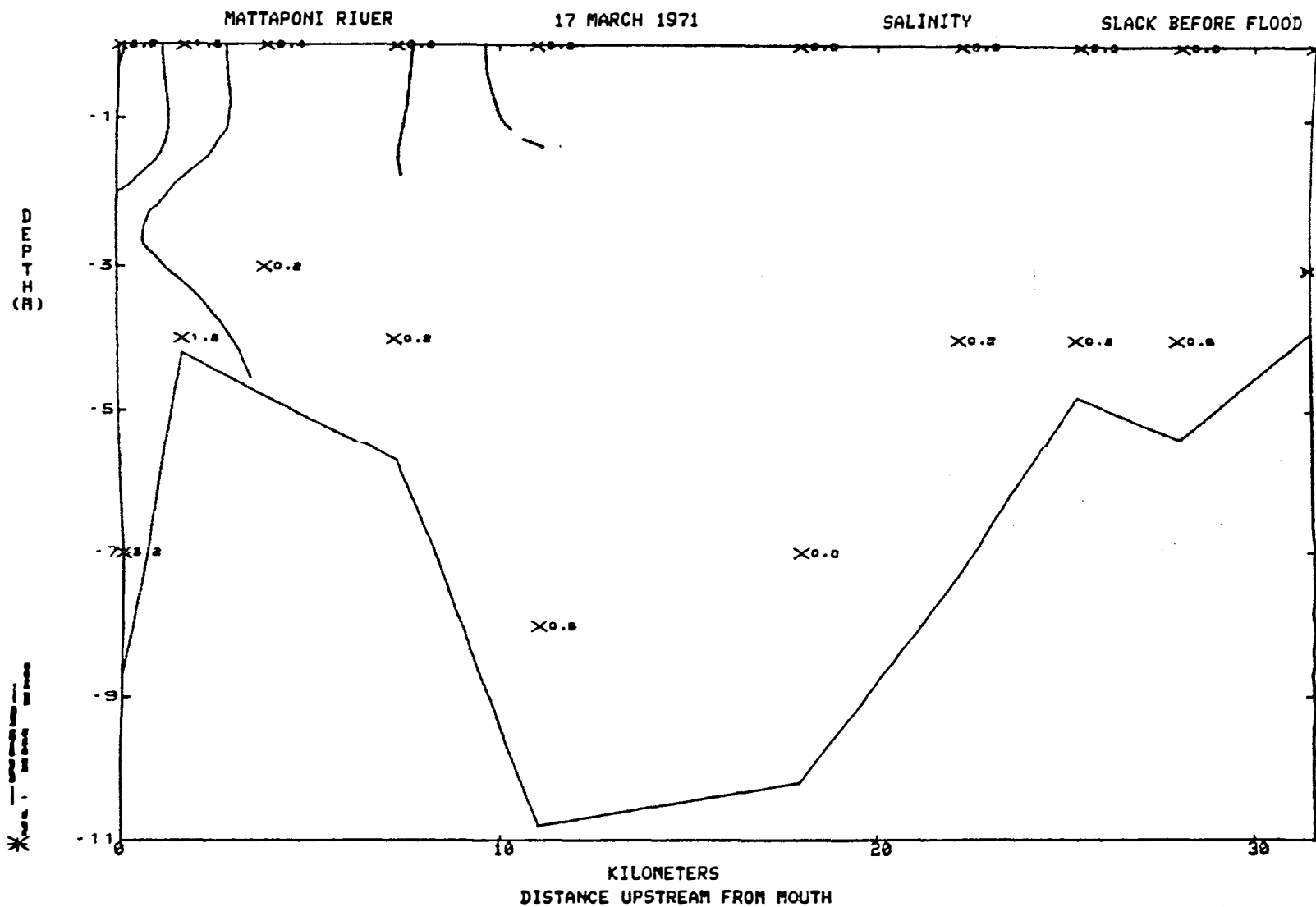


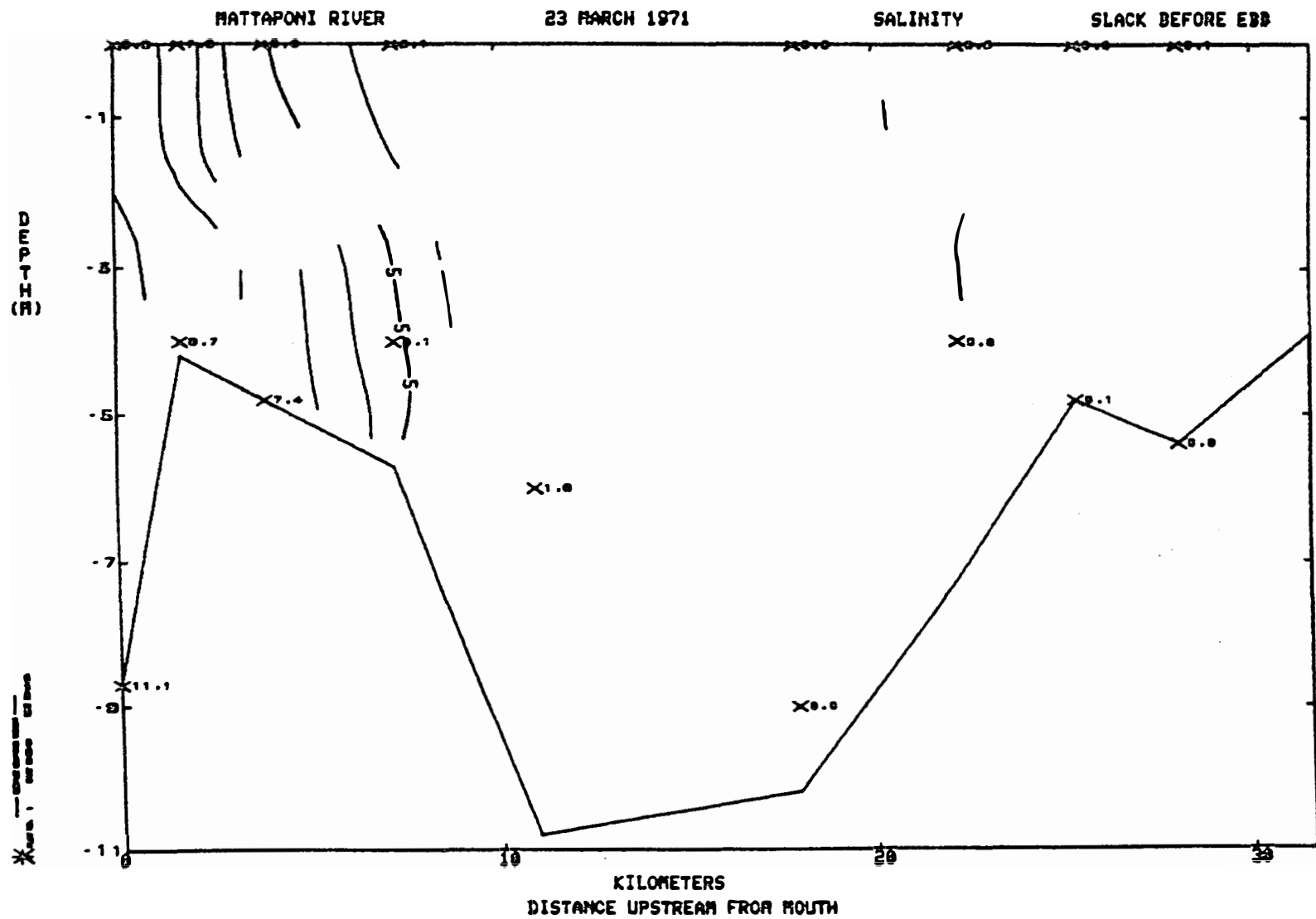


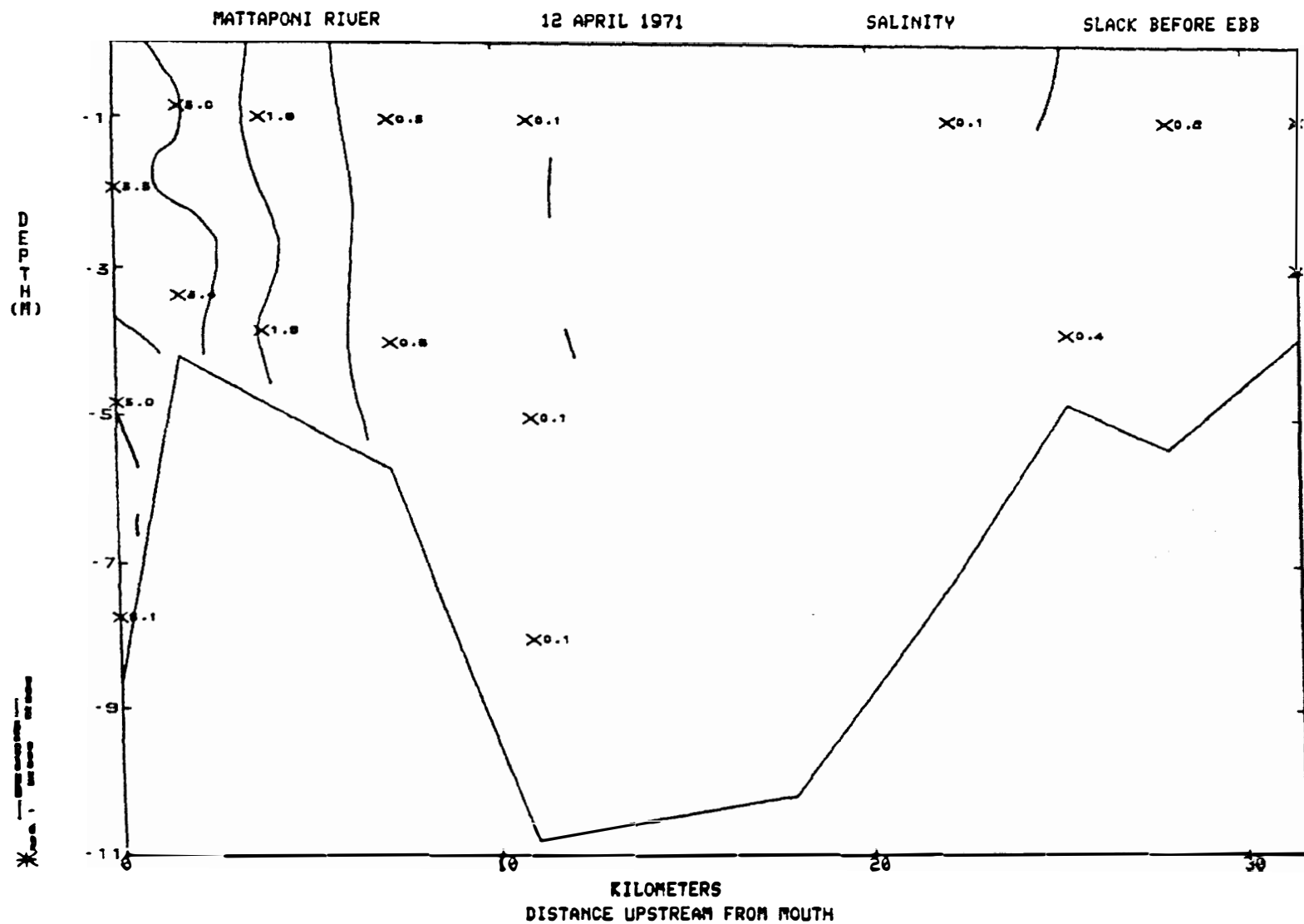


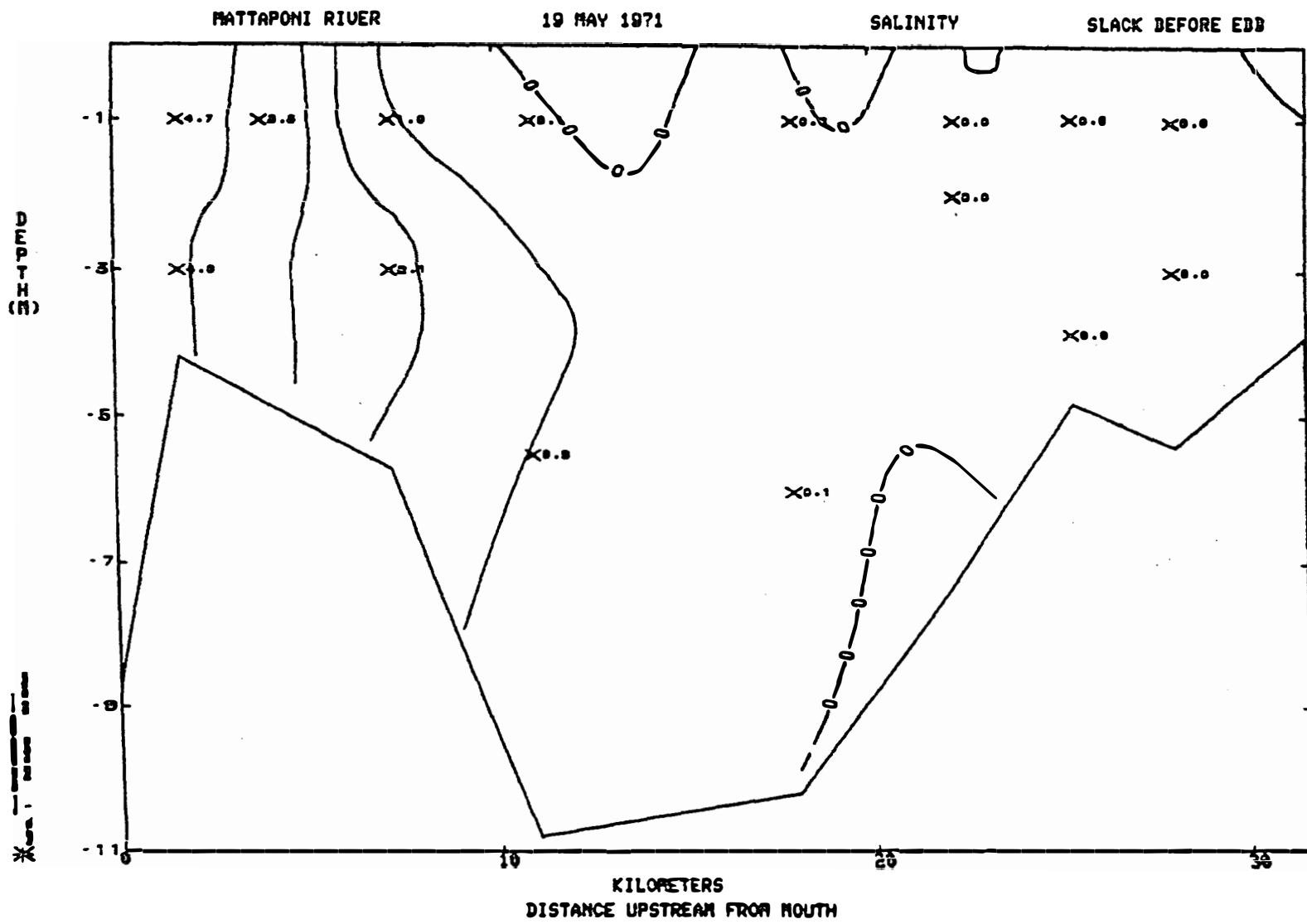
C. Salinity (ppt)

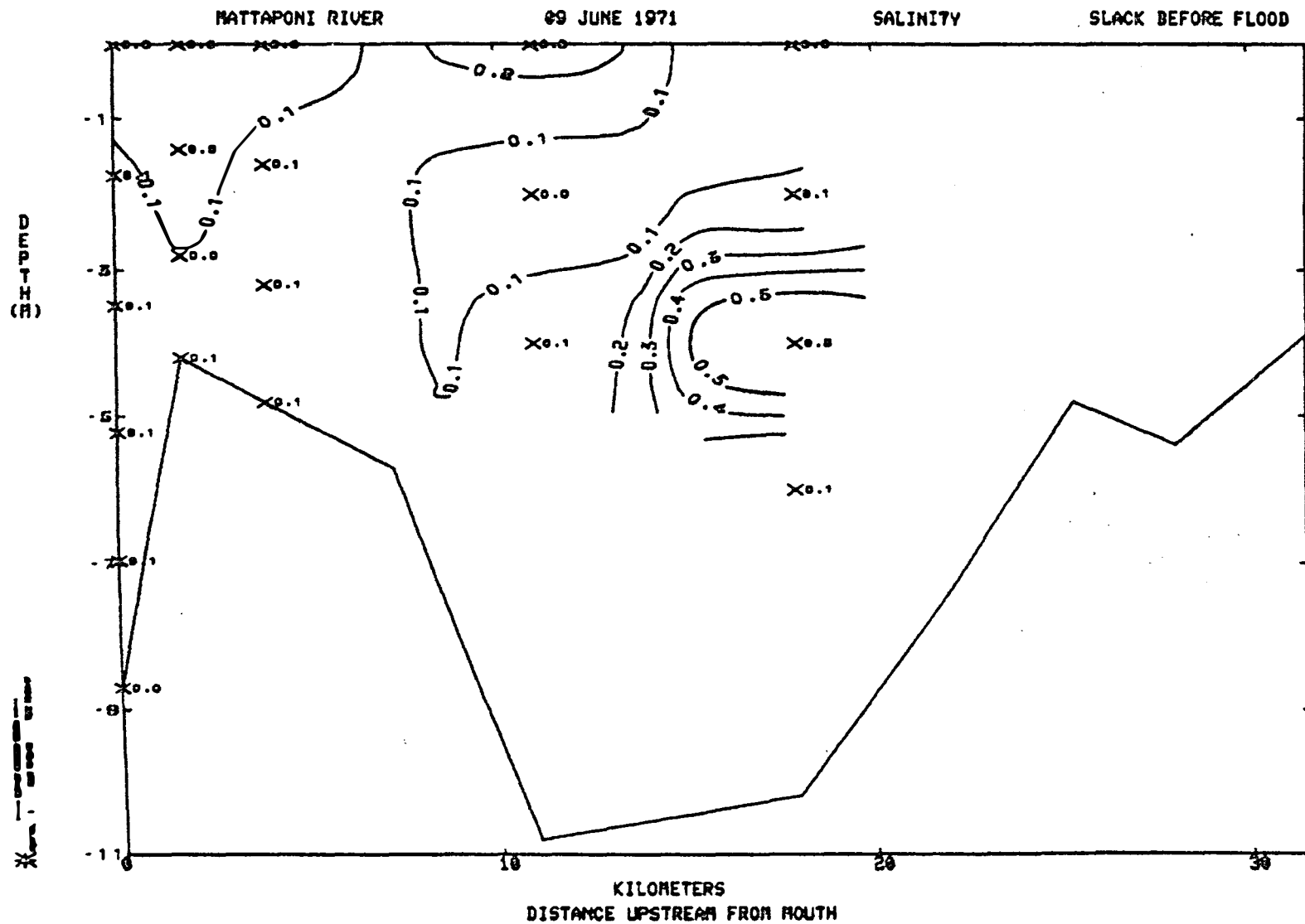


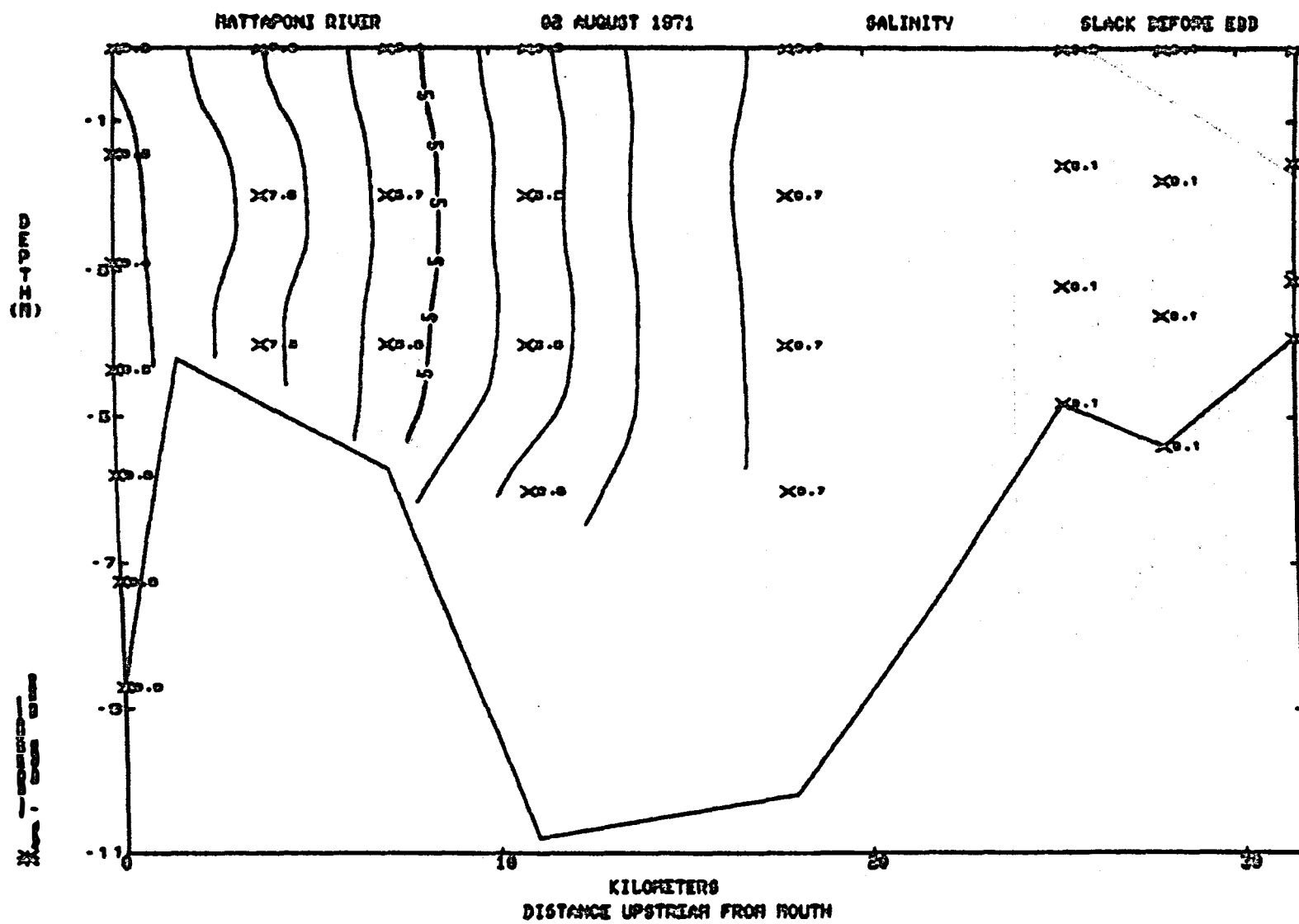


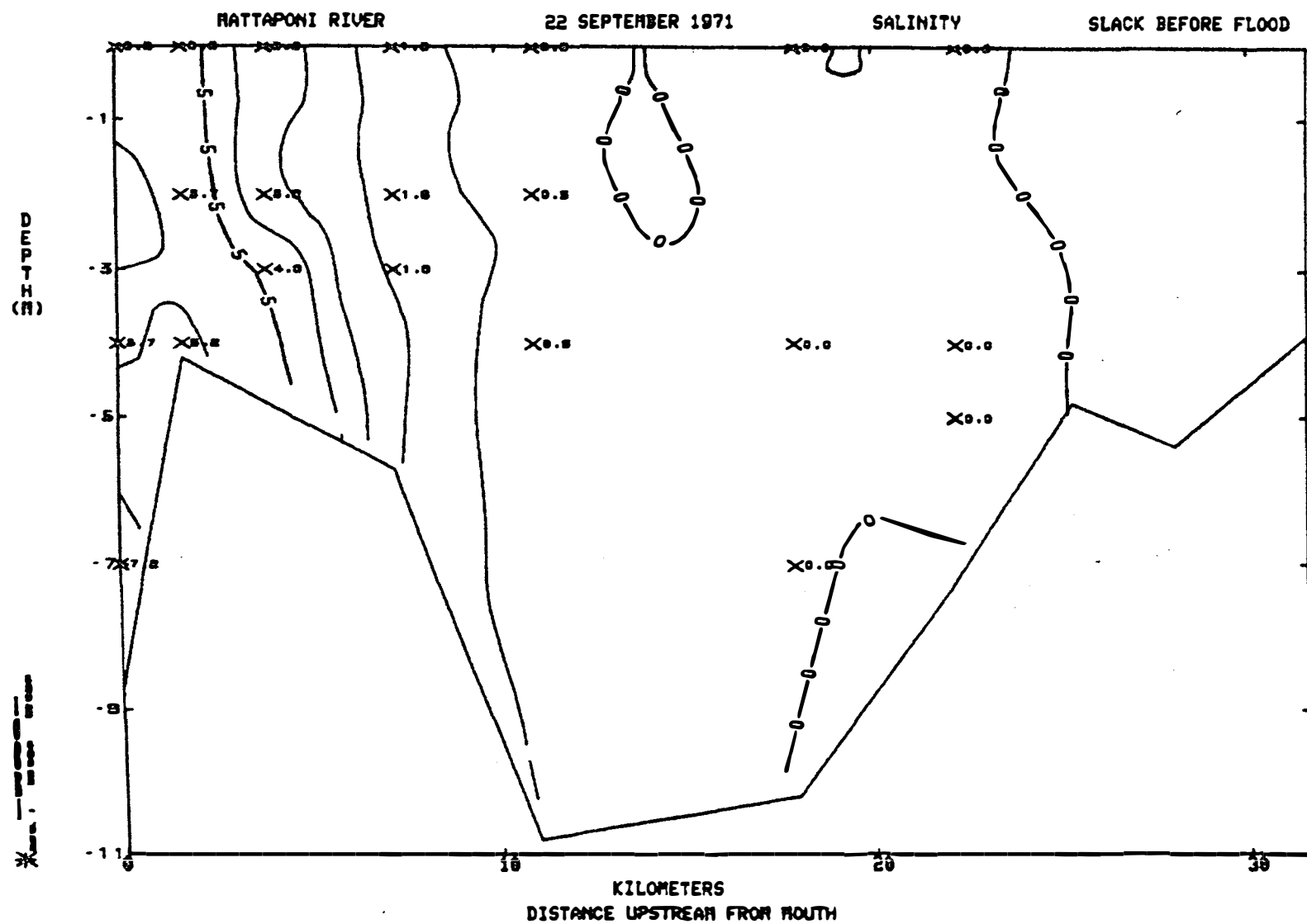


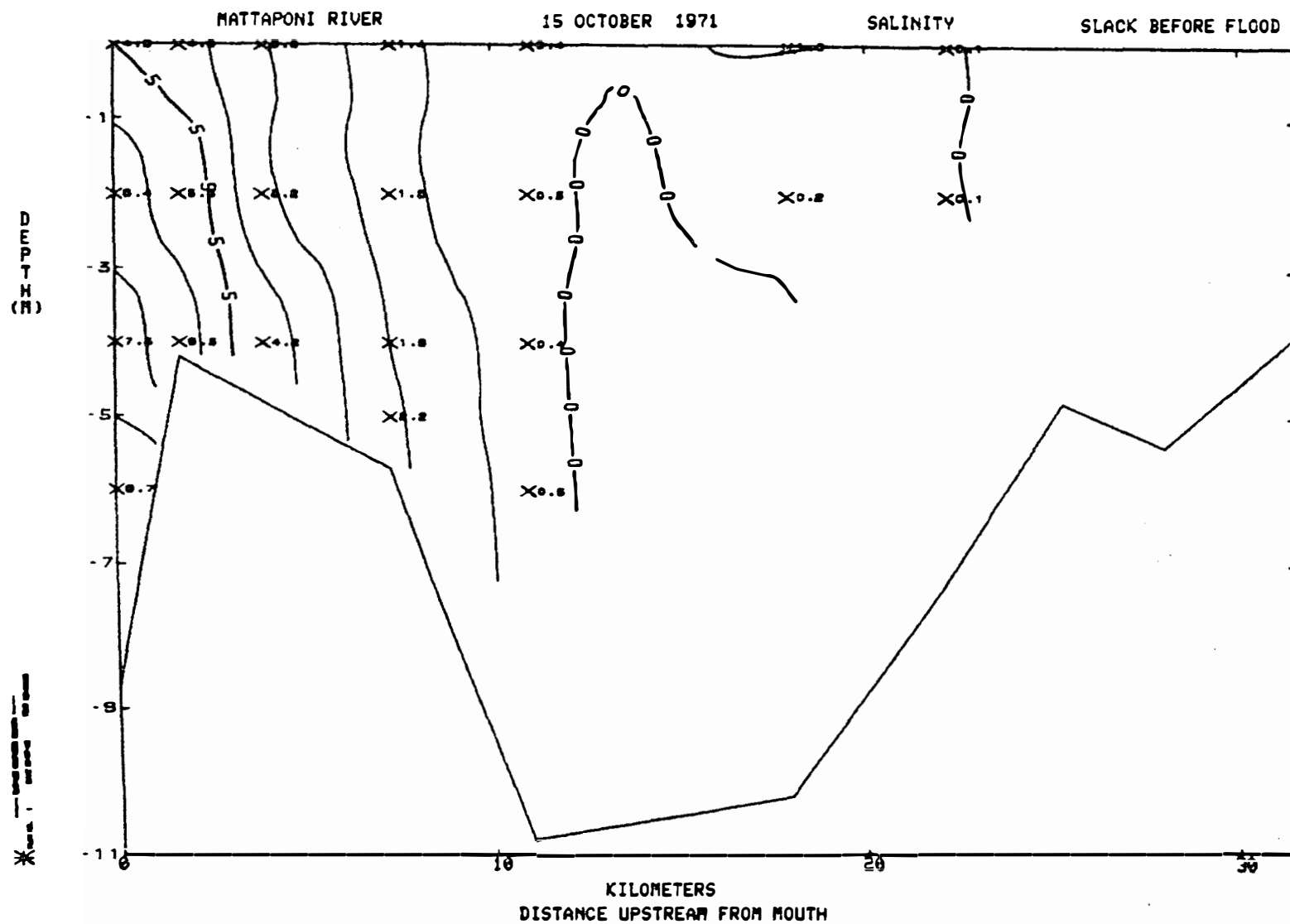


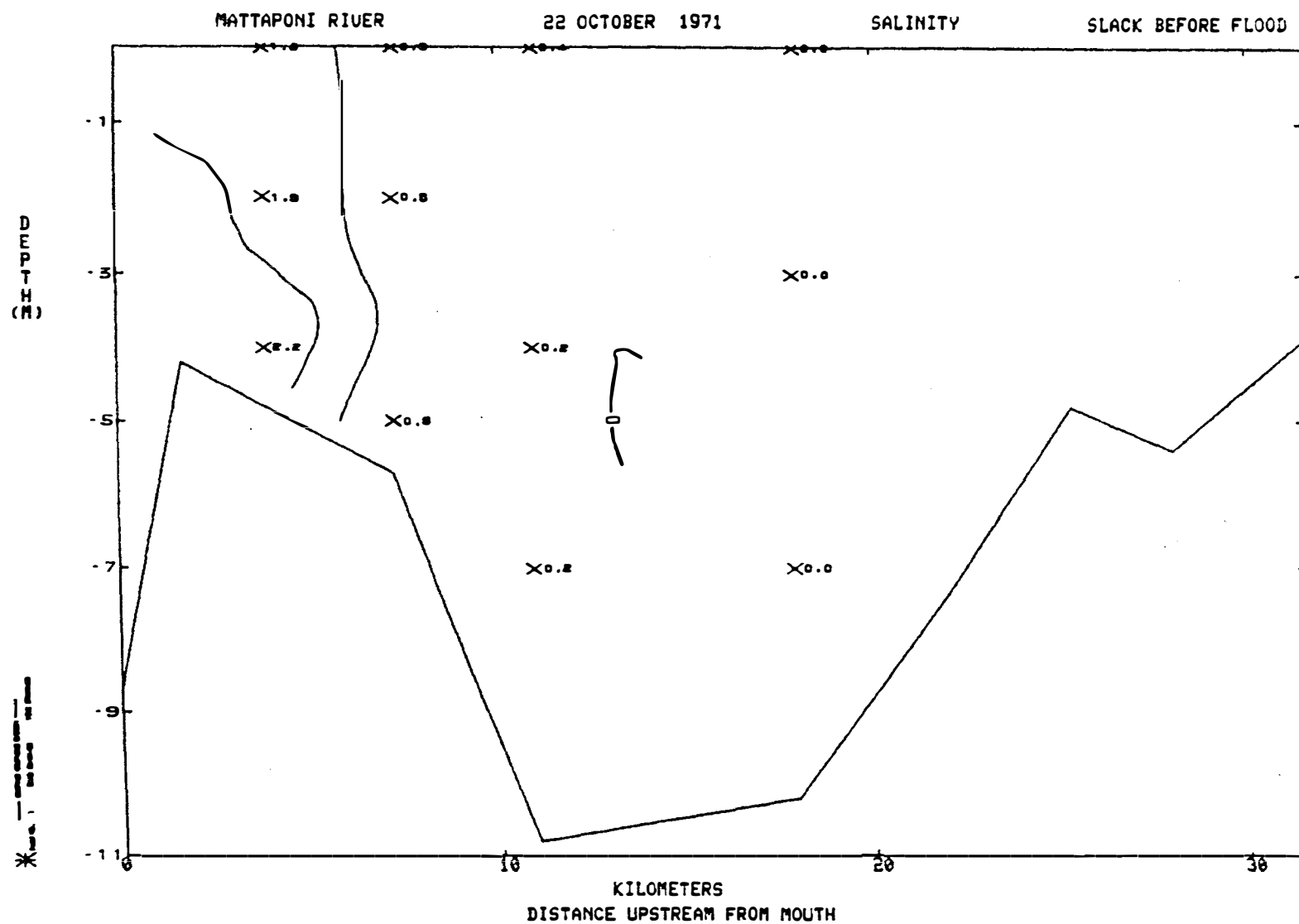


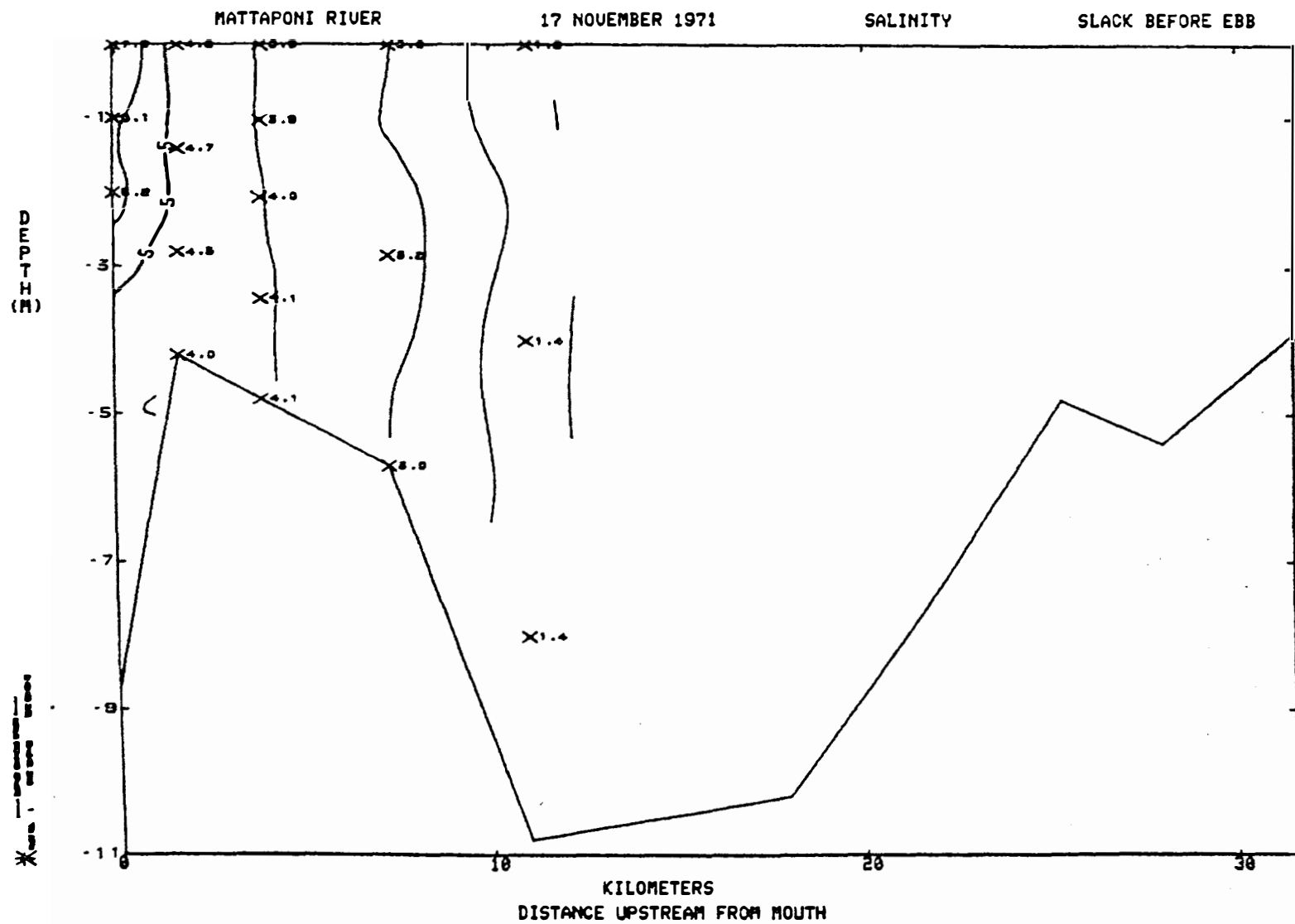


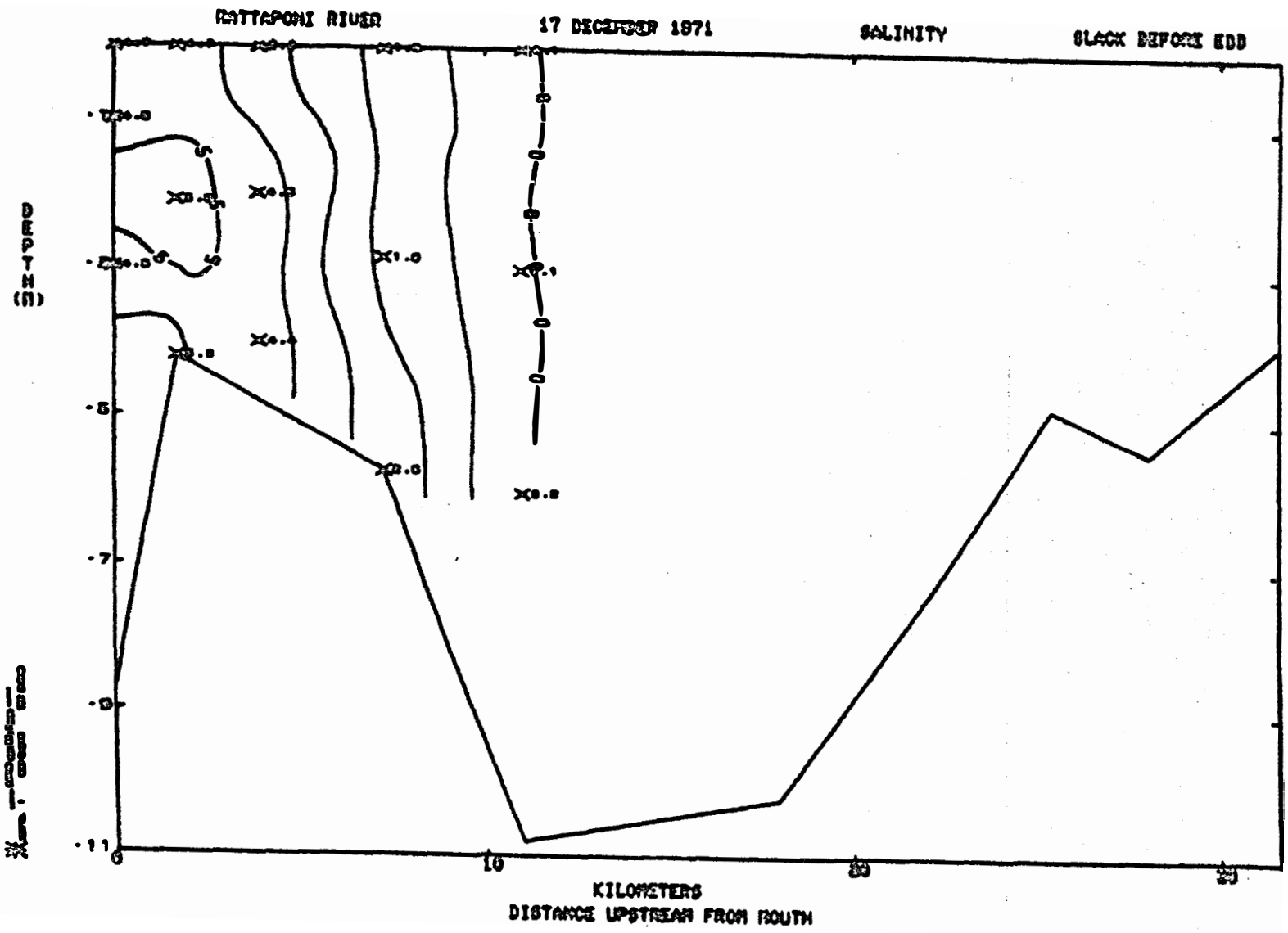


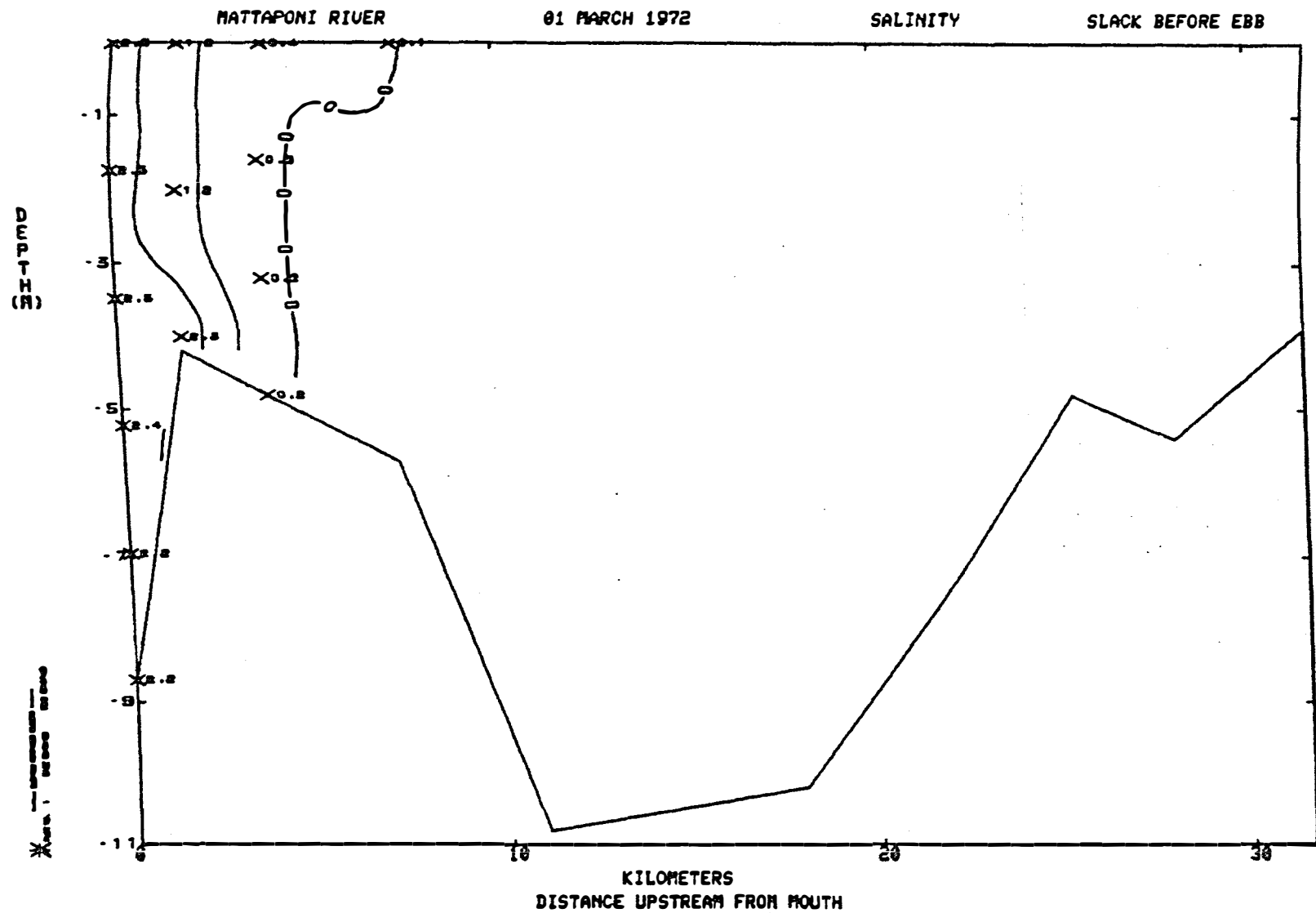


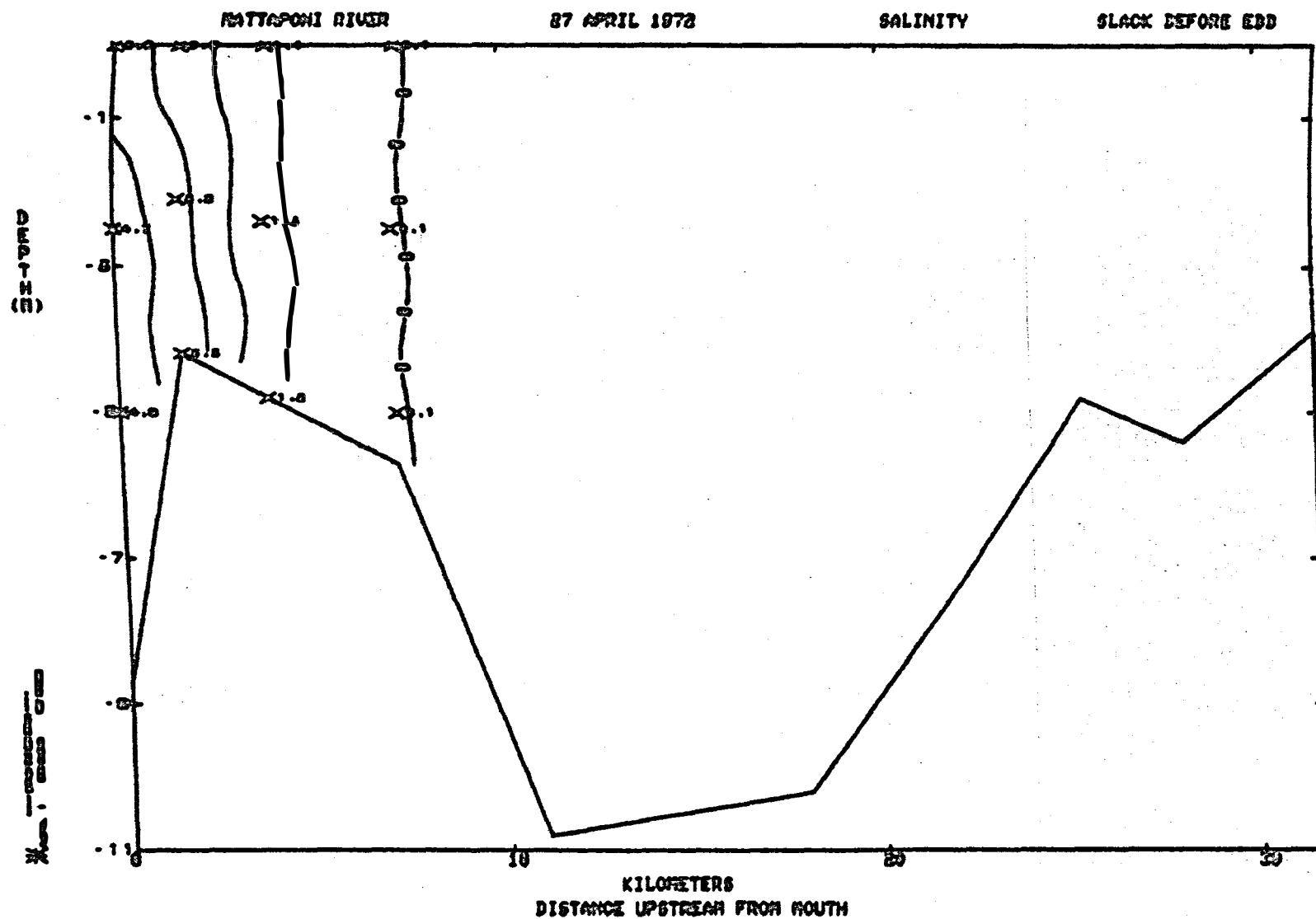


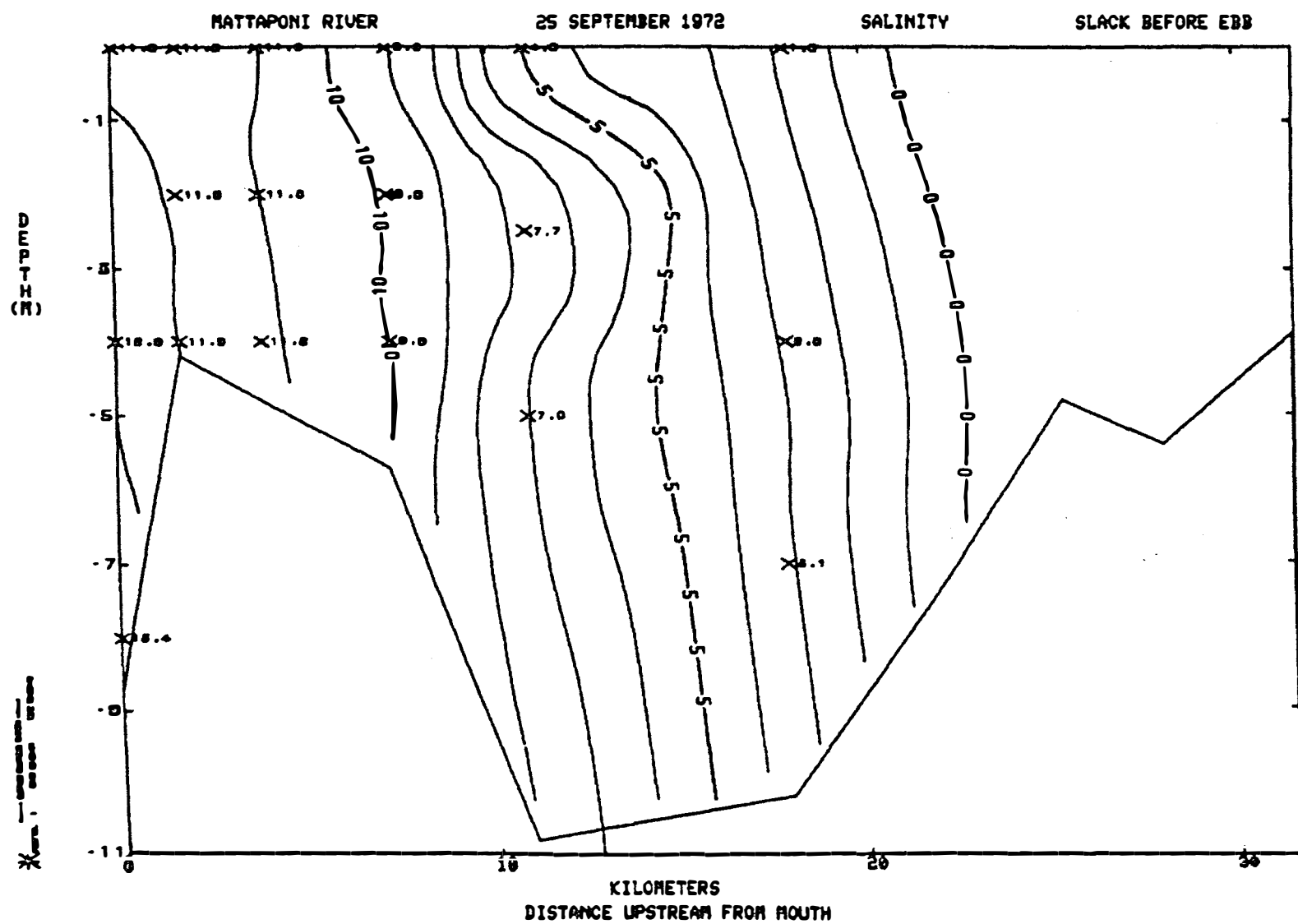


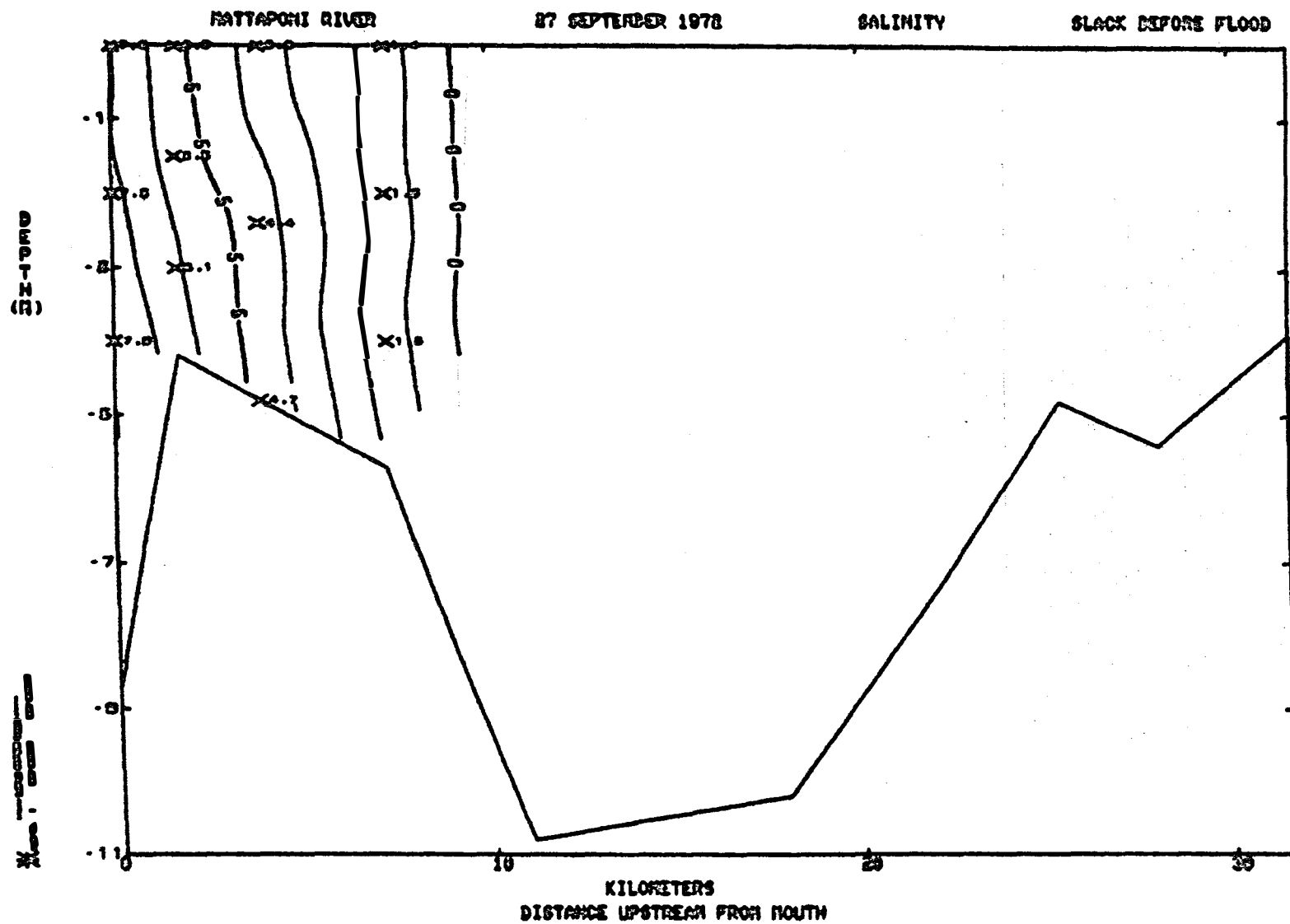


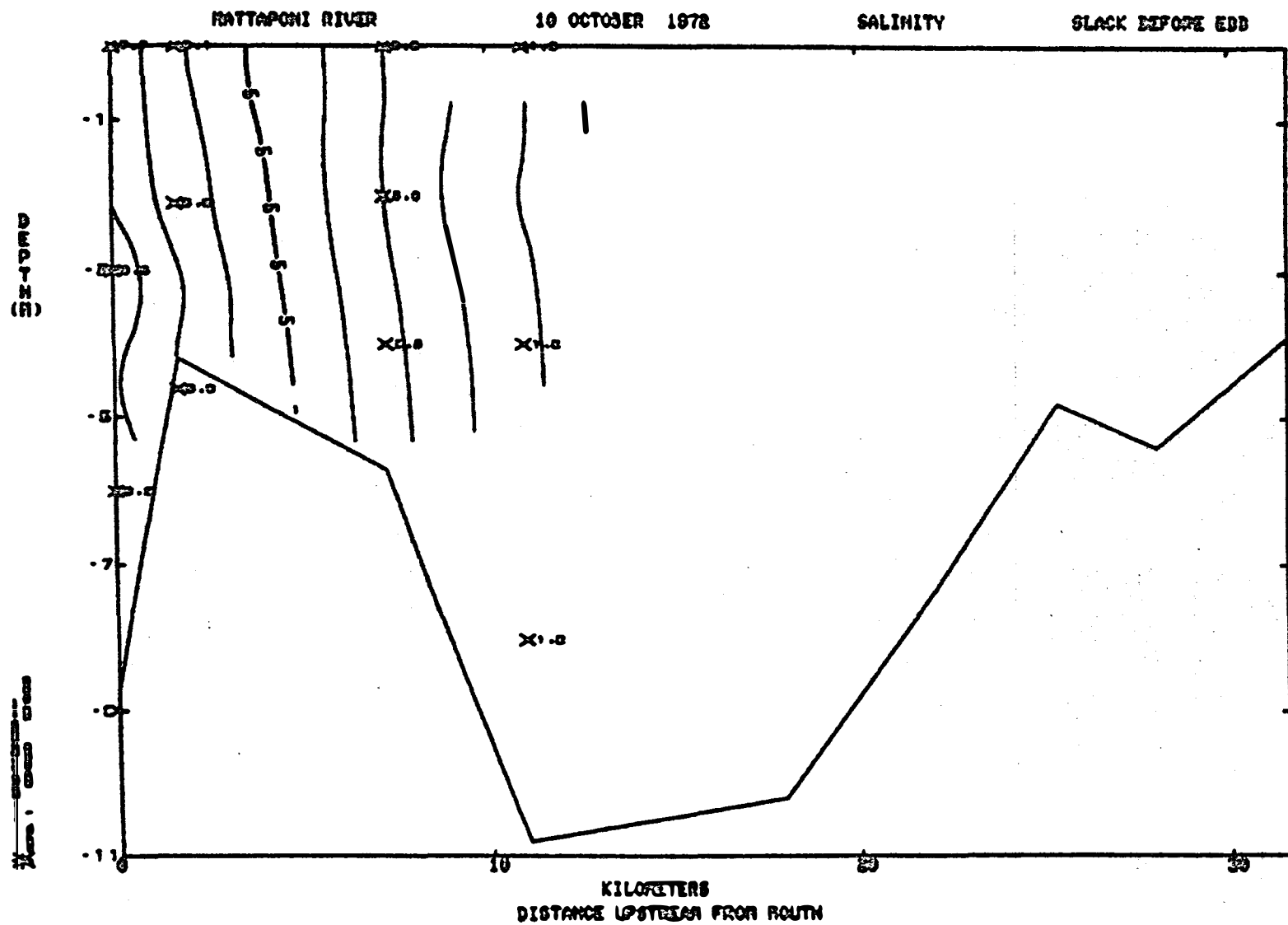


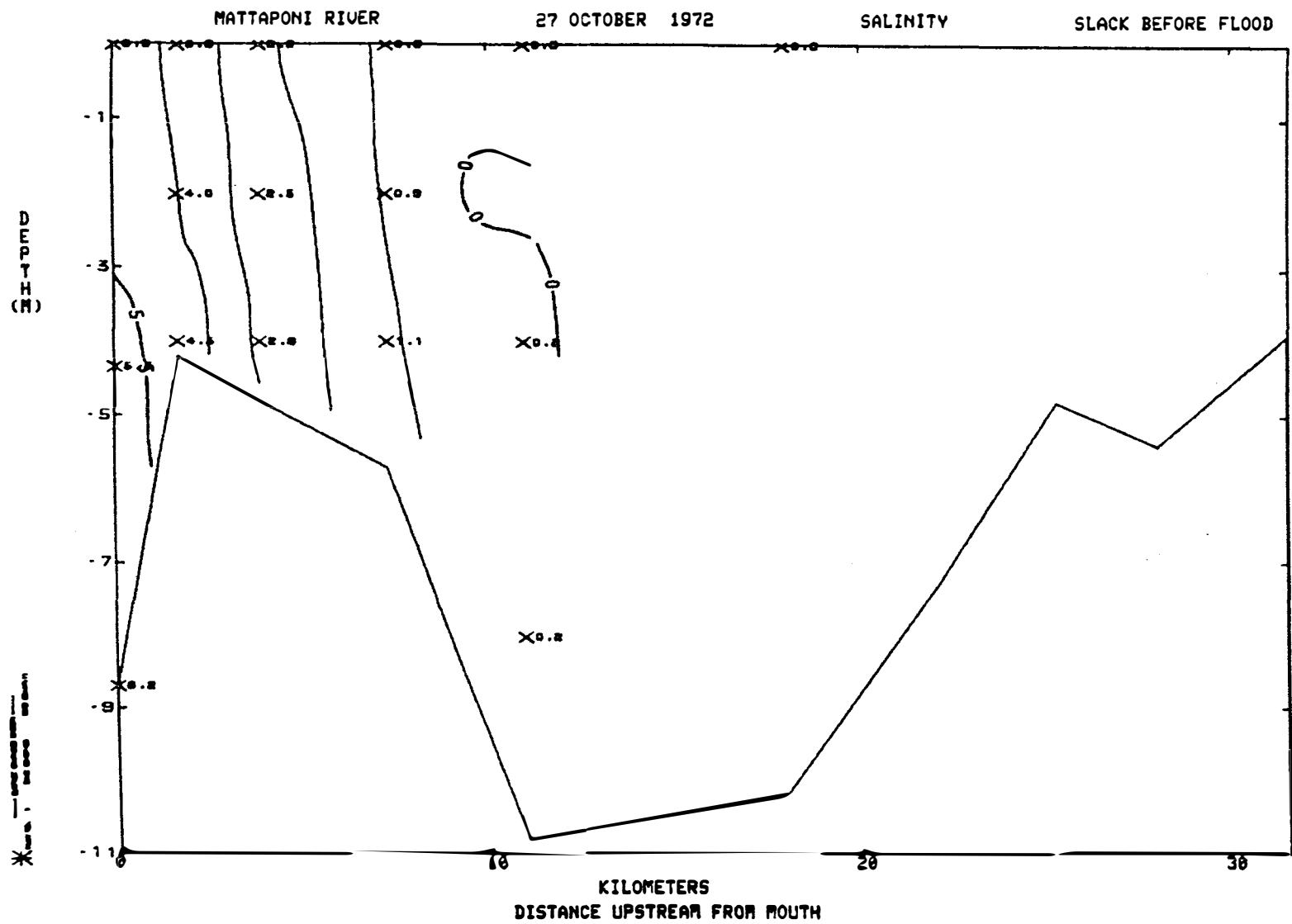


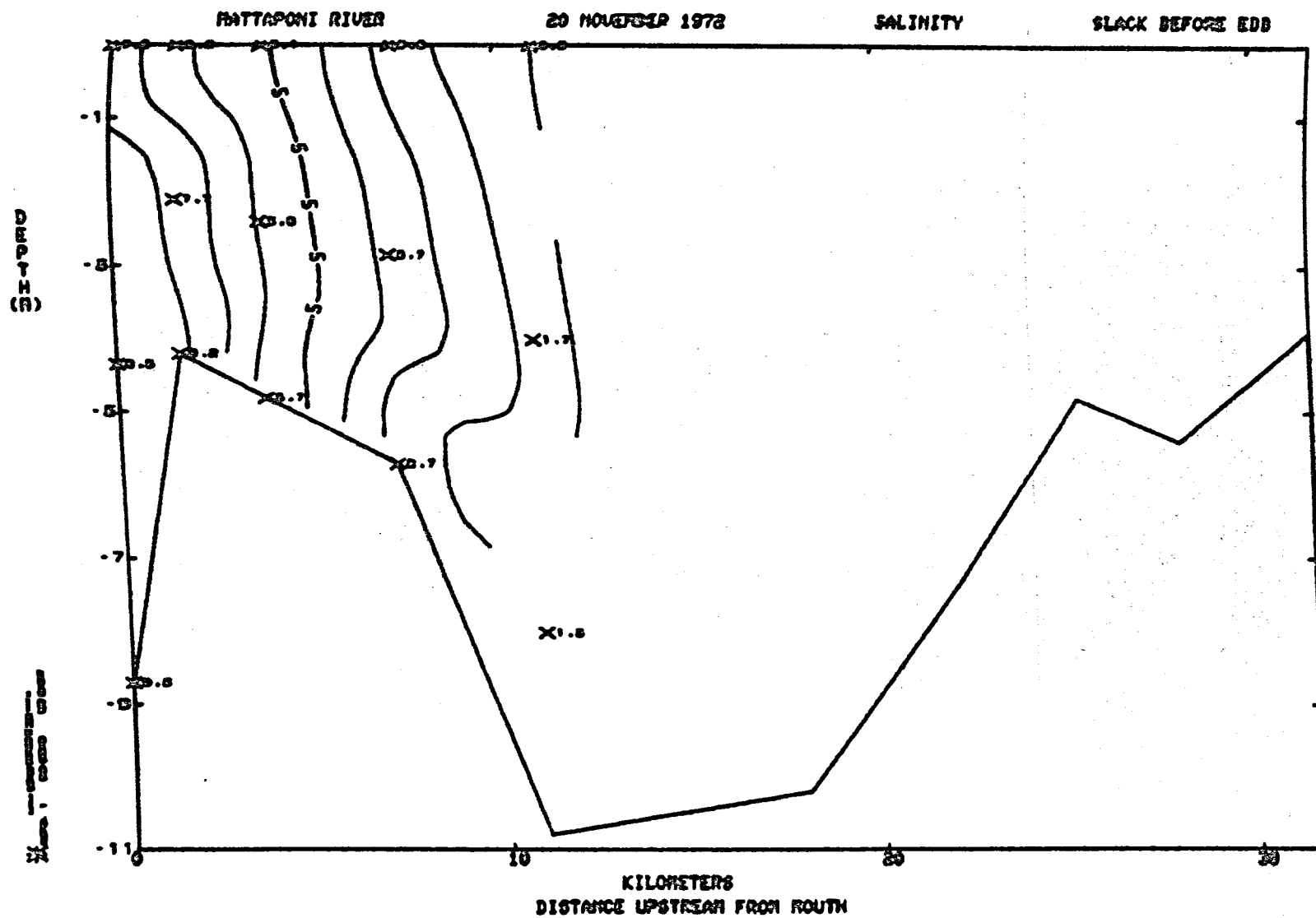


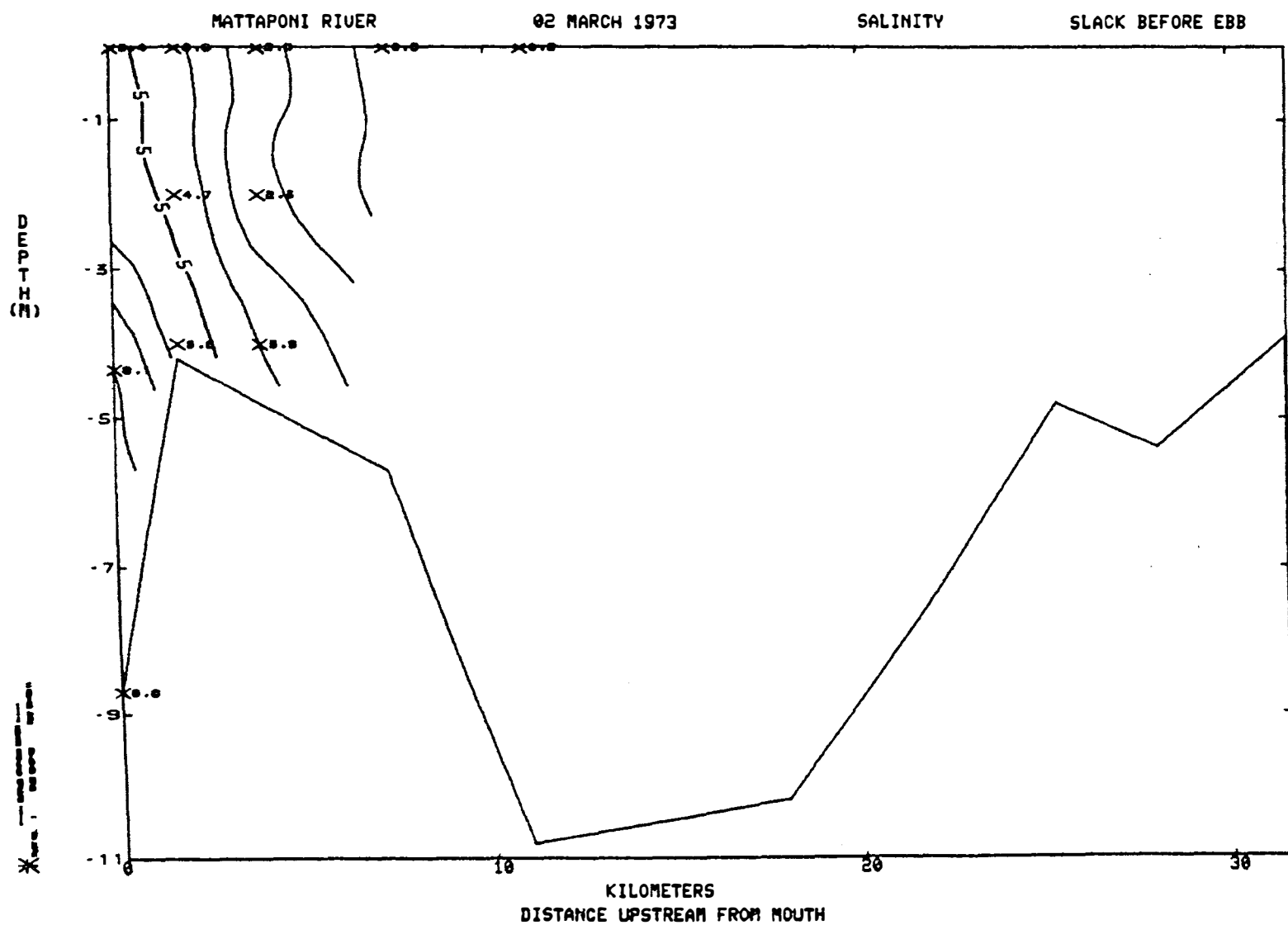


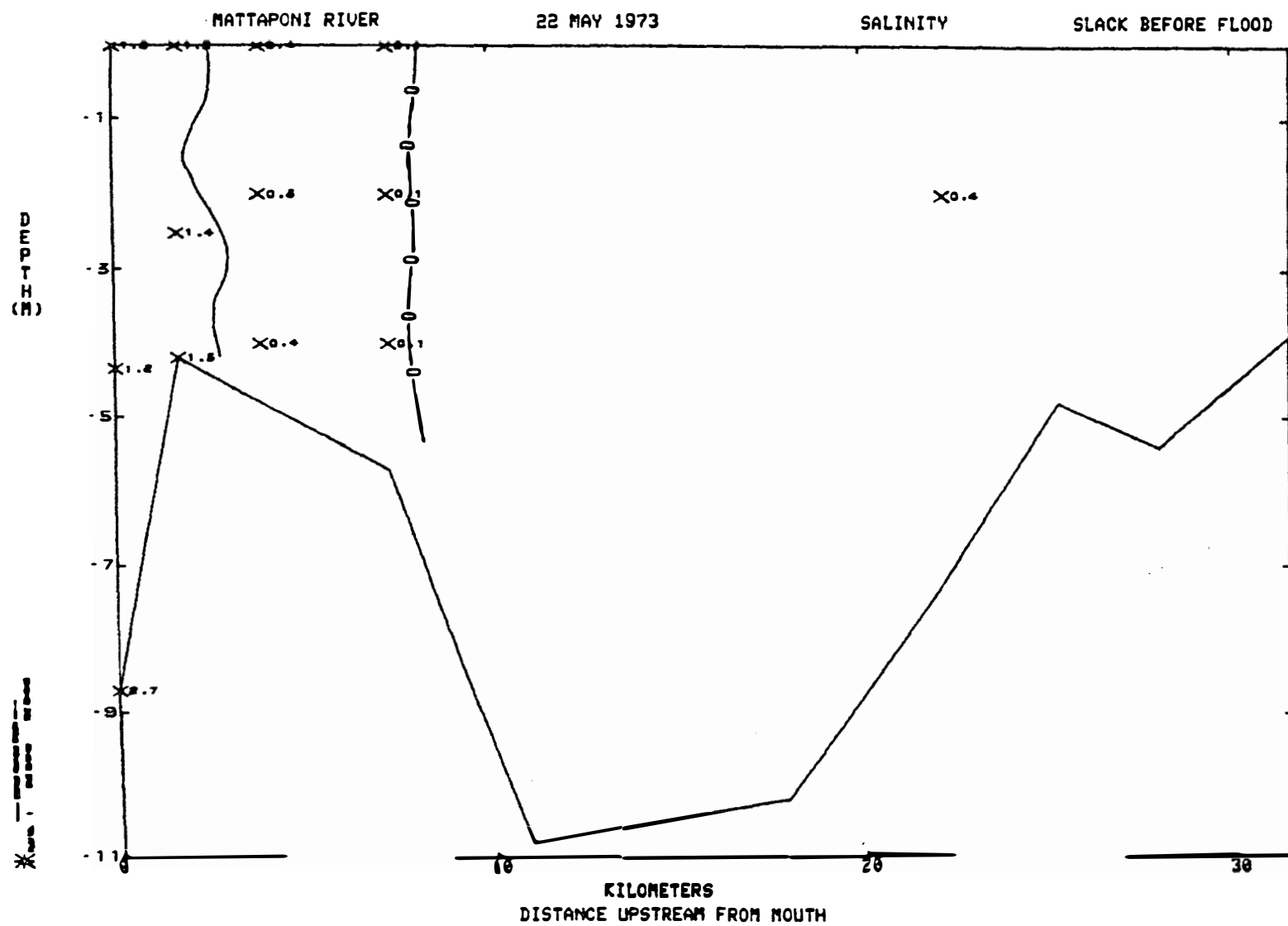


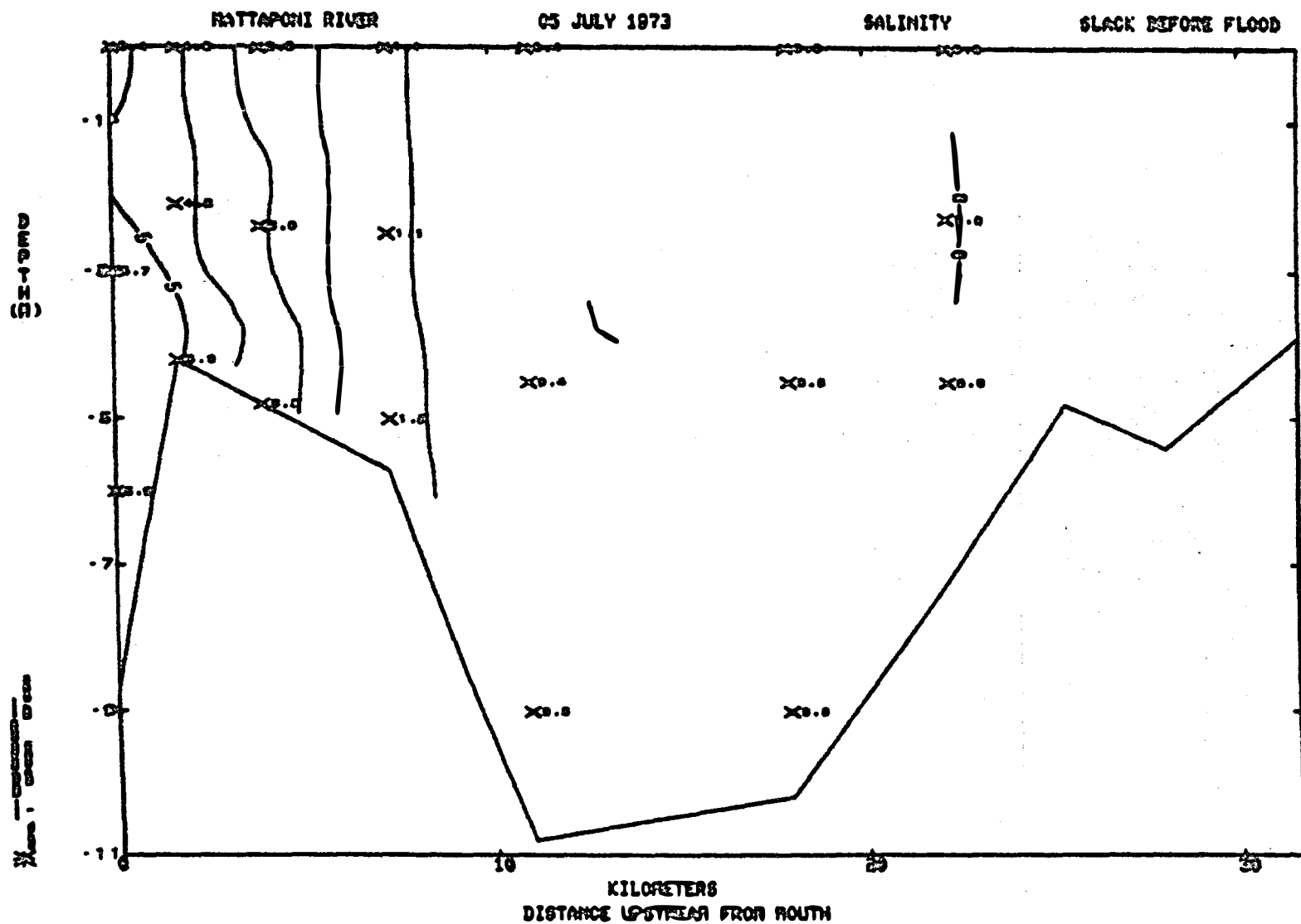


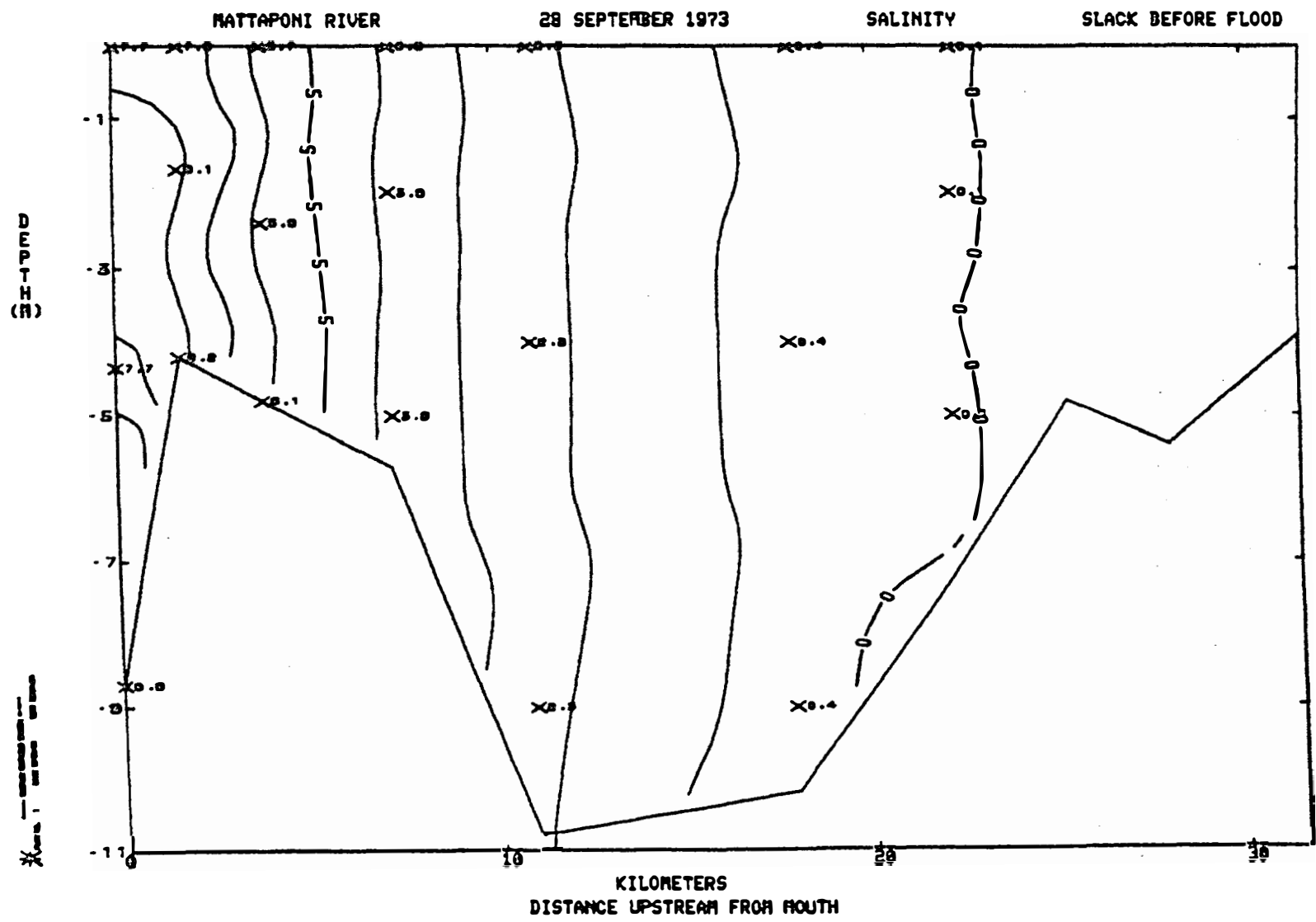




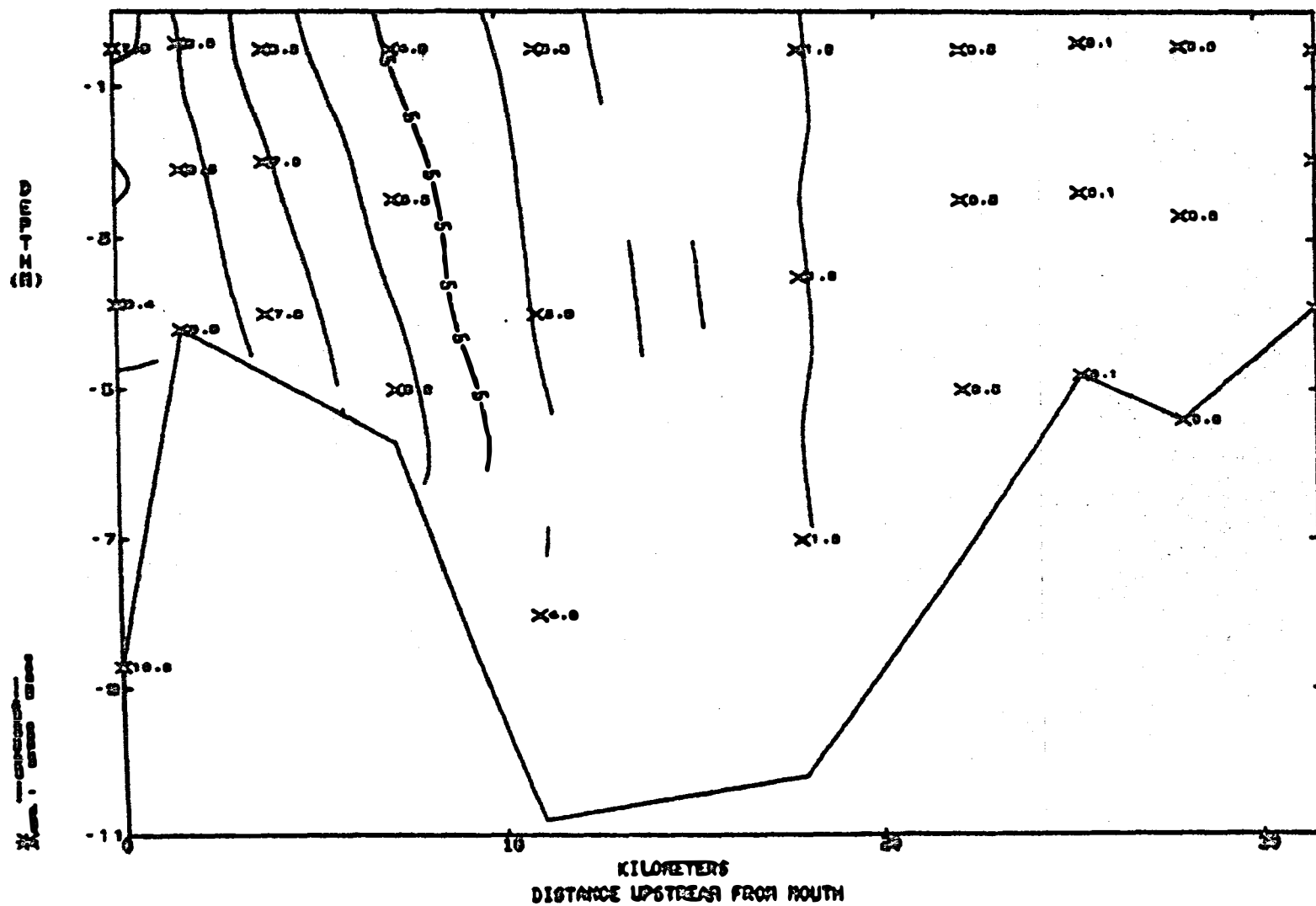


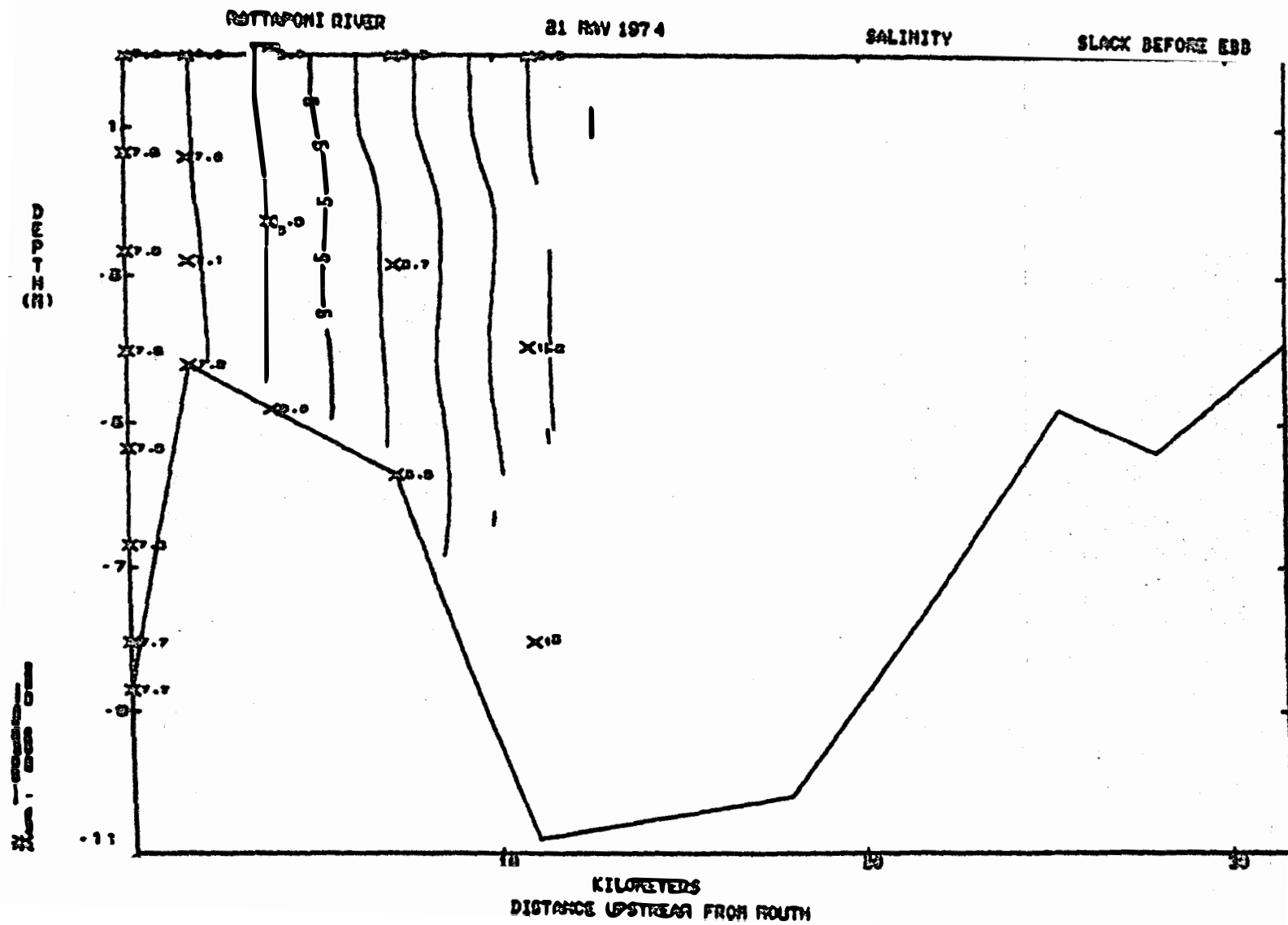


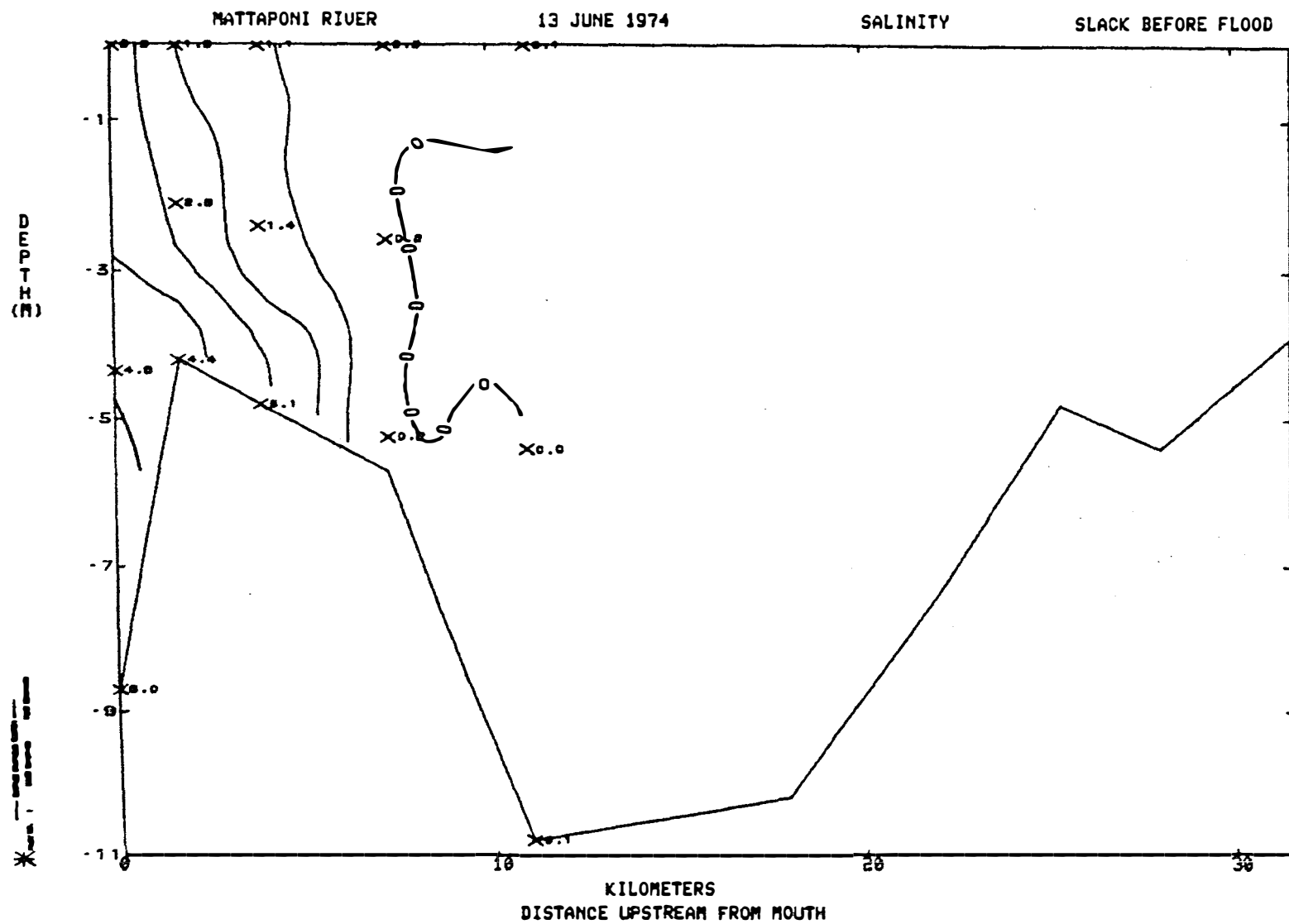


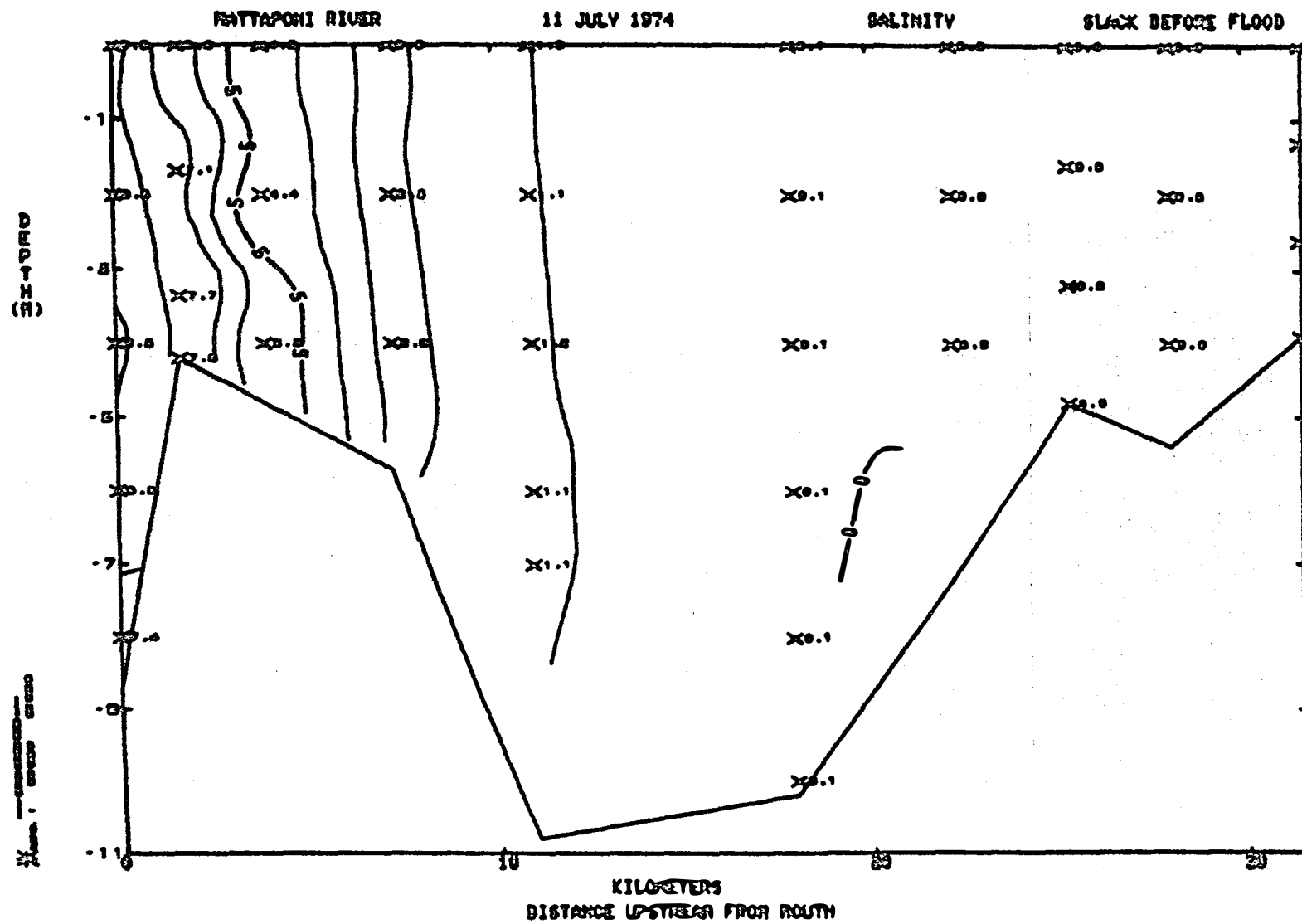


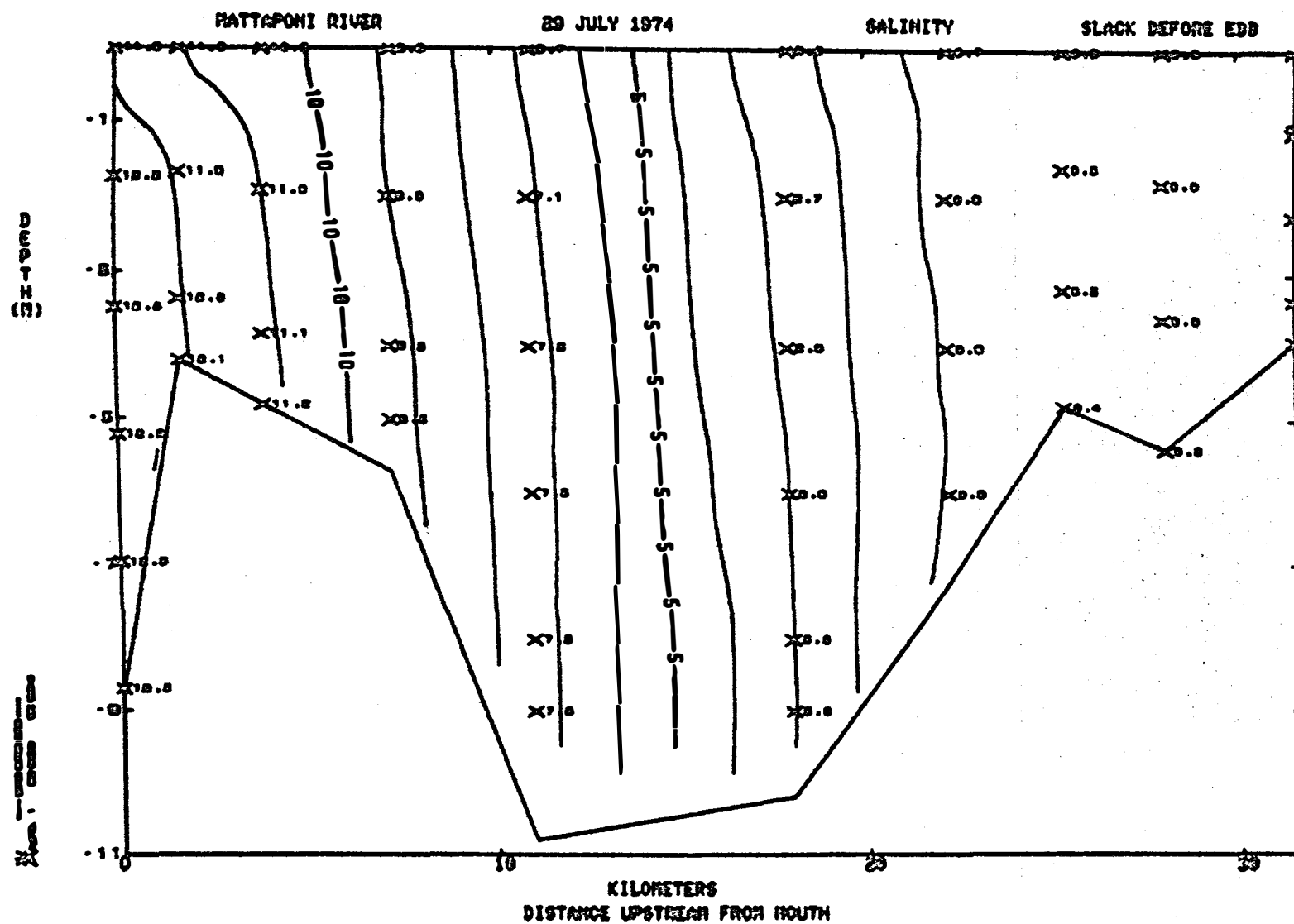
BLACK BEFORE FLOOD

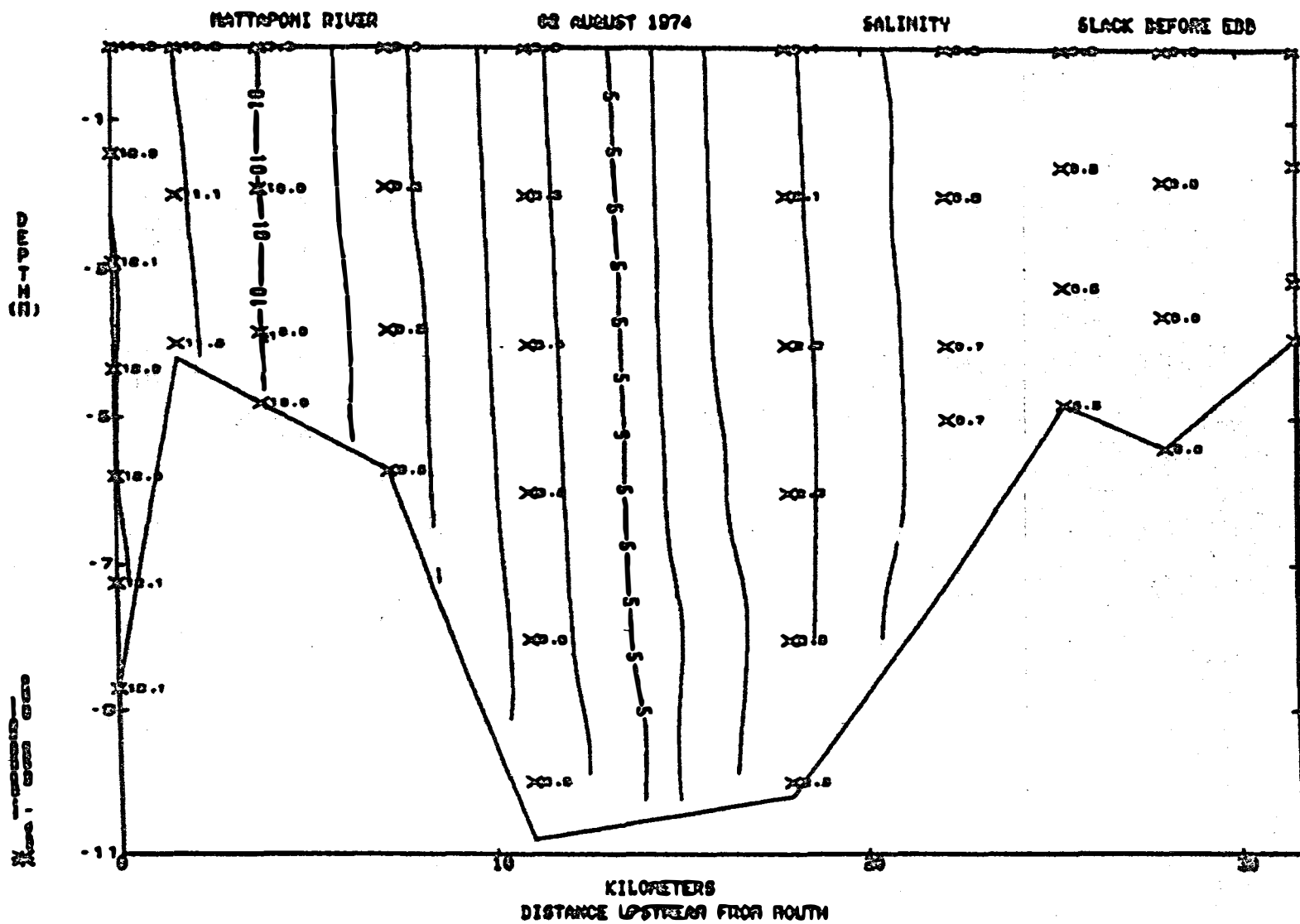


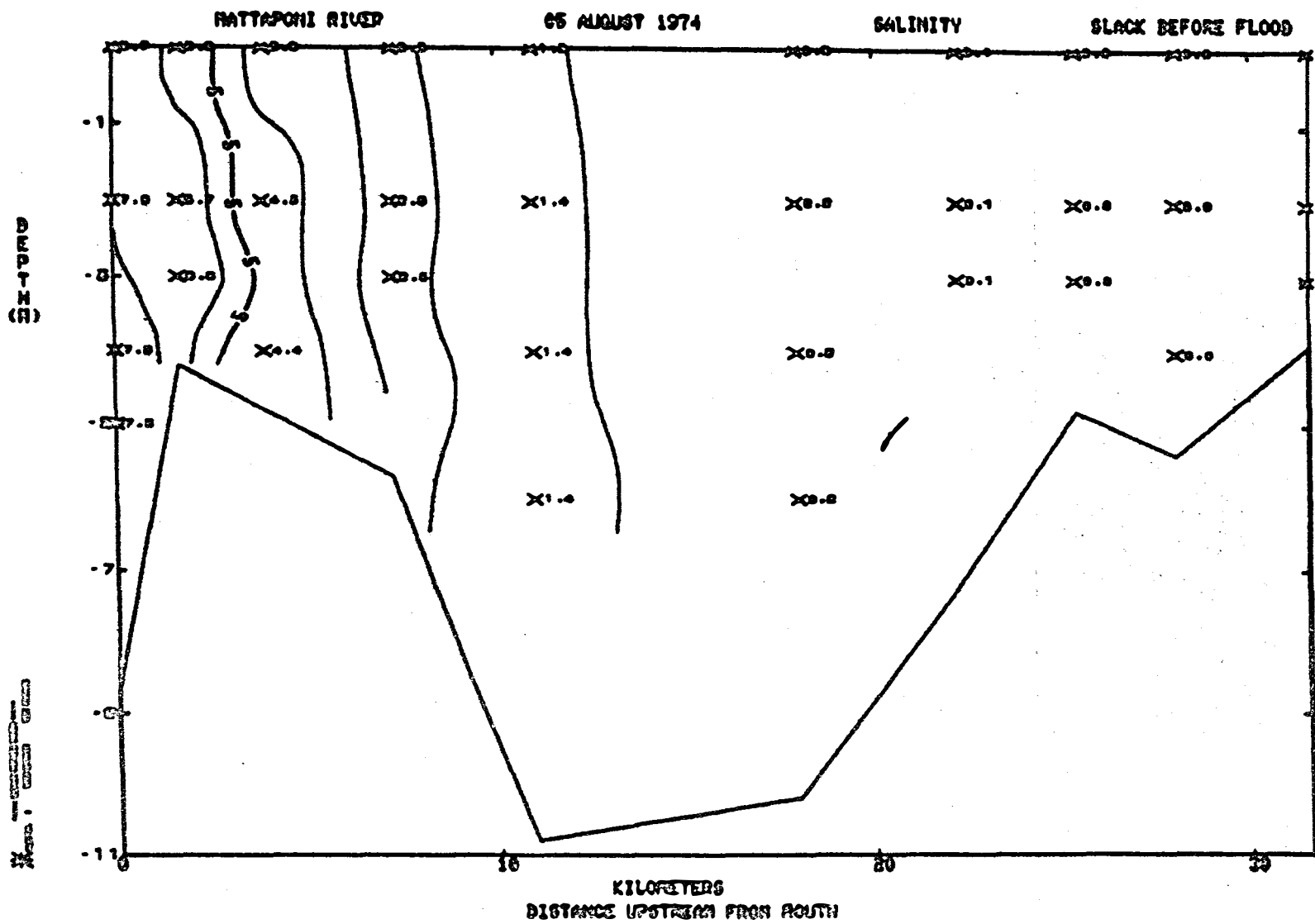


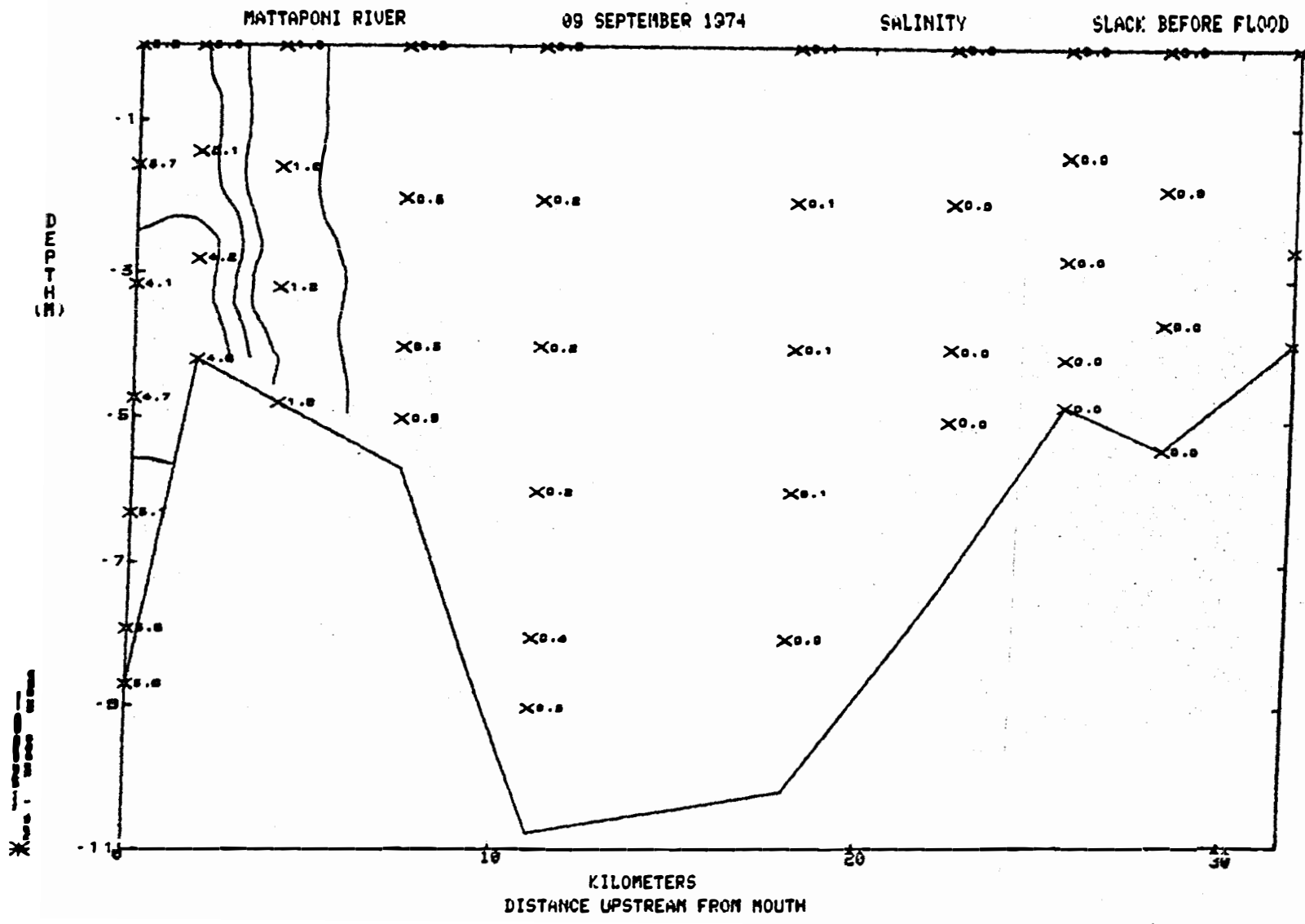


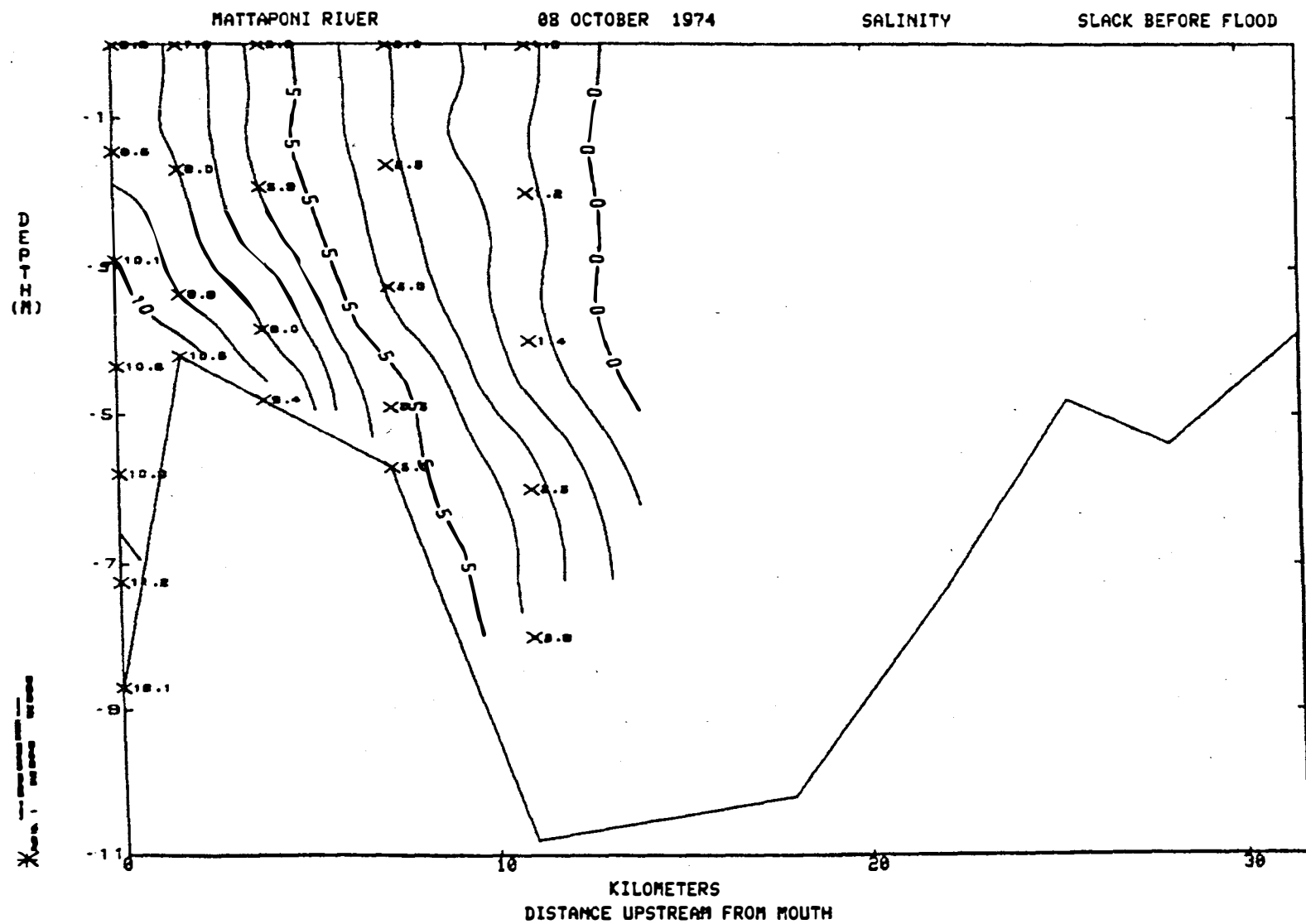


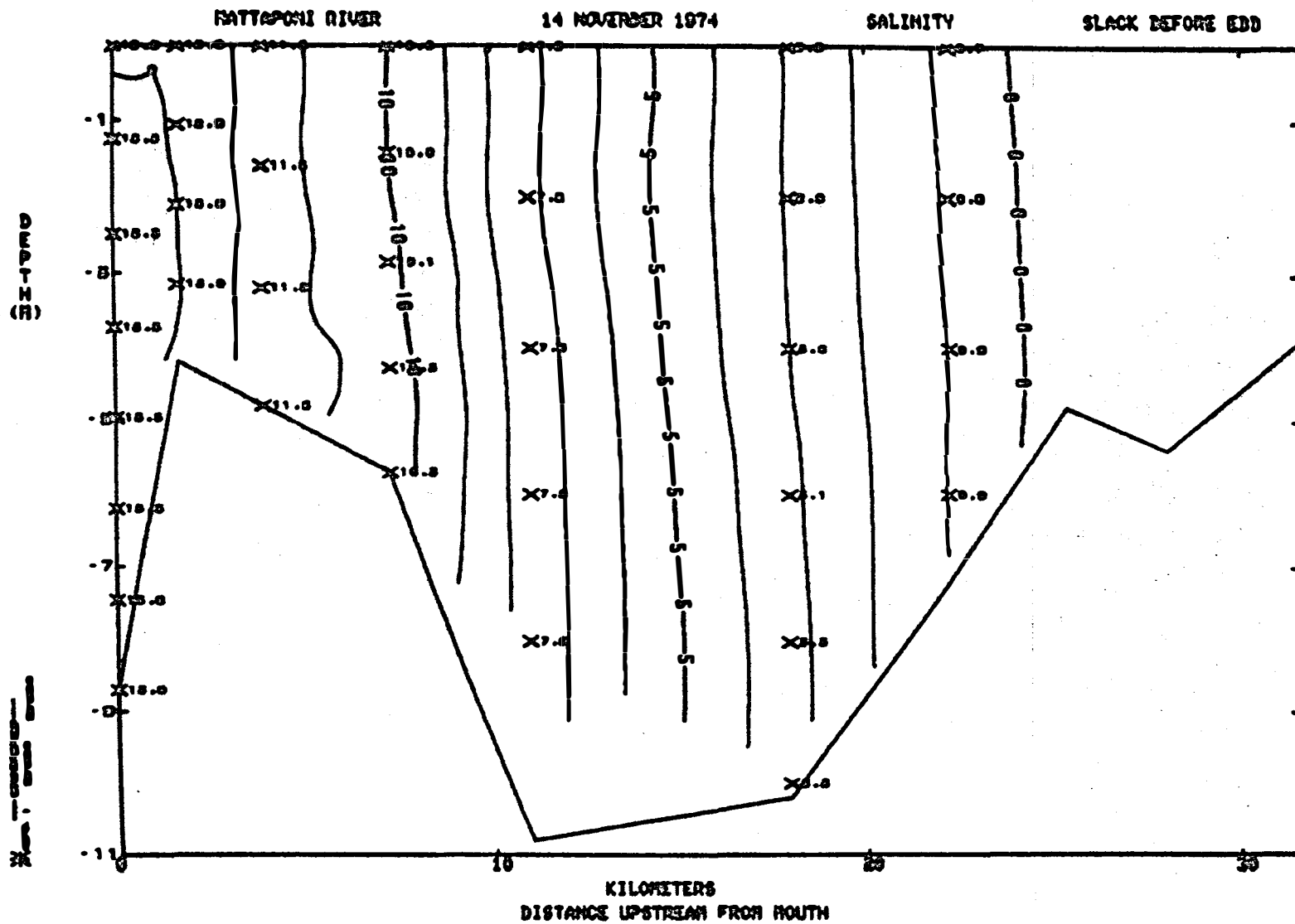


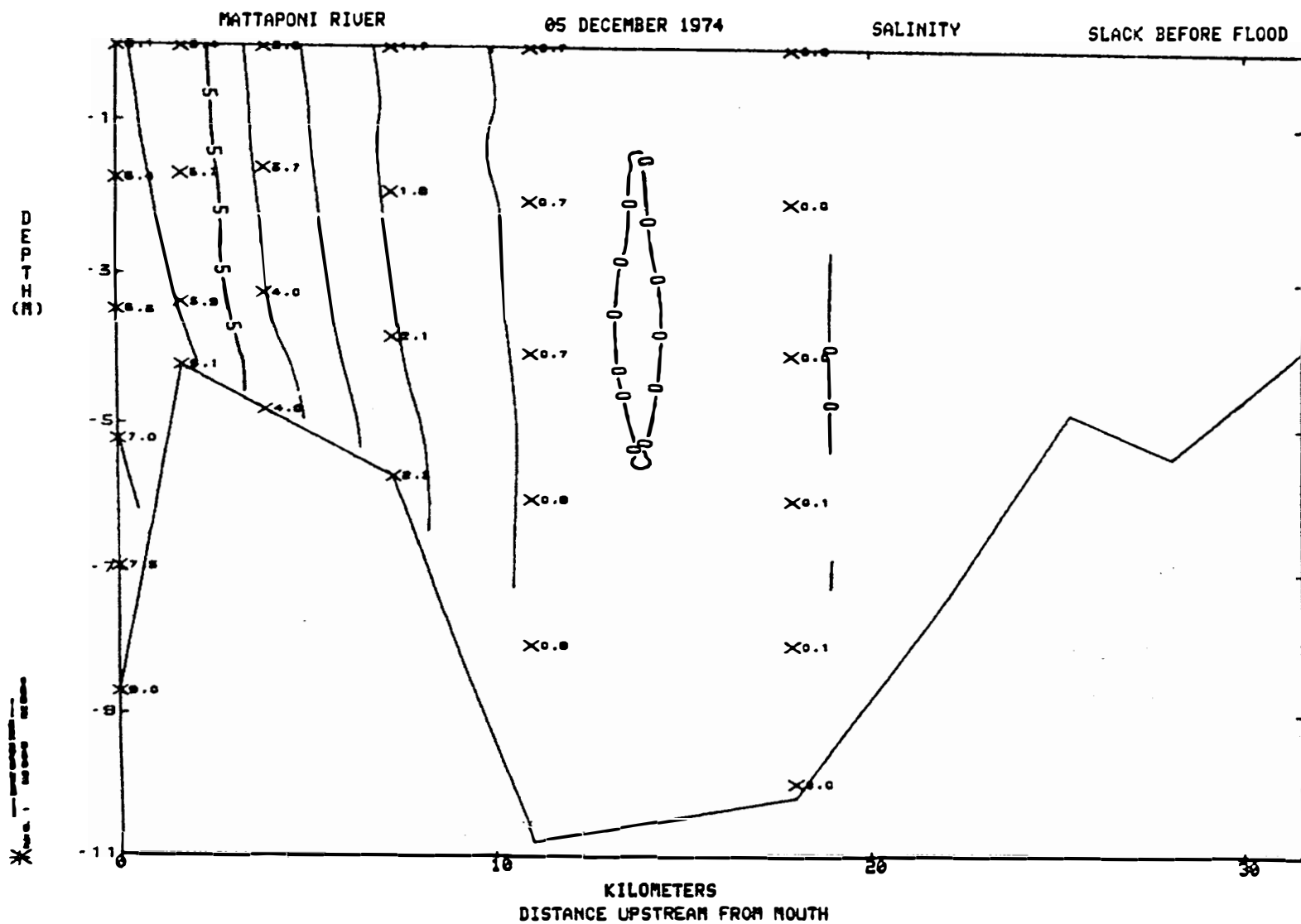










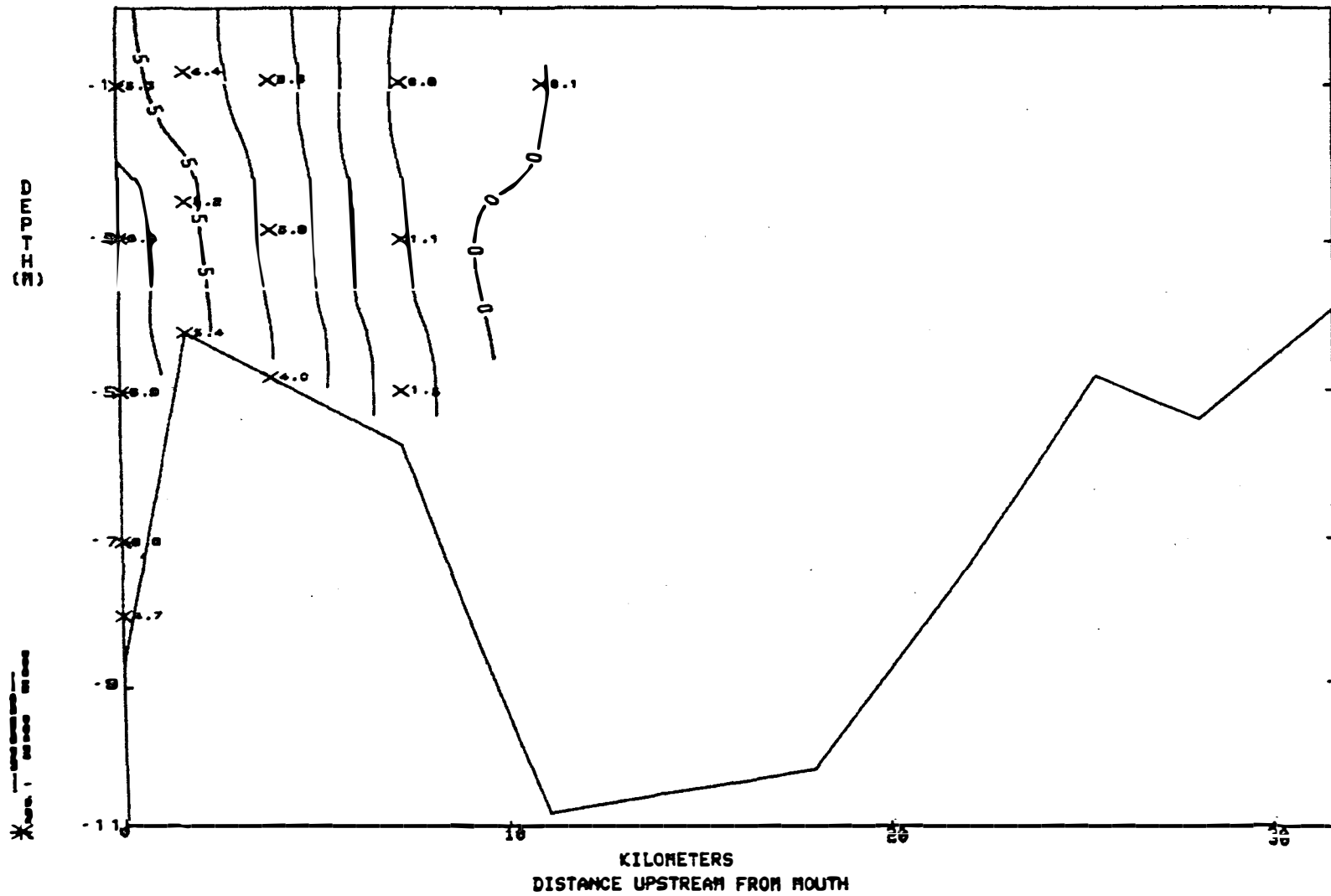


MATTAPONI RIVER

09 MAY 1975

SALINITY

SLACK BEFORE EBB

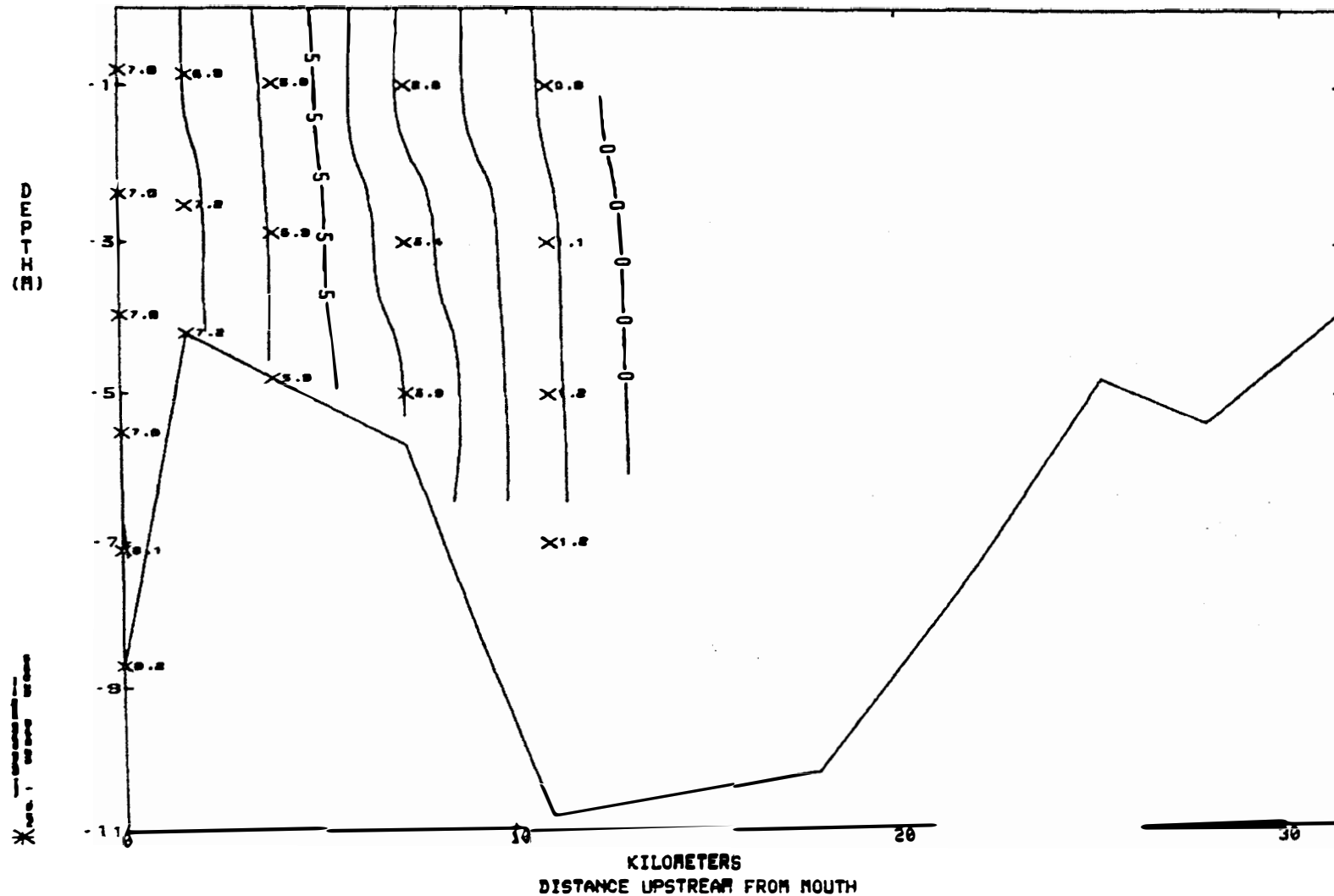


MATTAPONI RIVER

17 OCTOBER 1975

SALINITY

SLACK BEFORE EBB

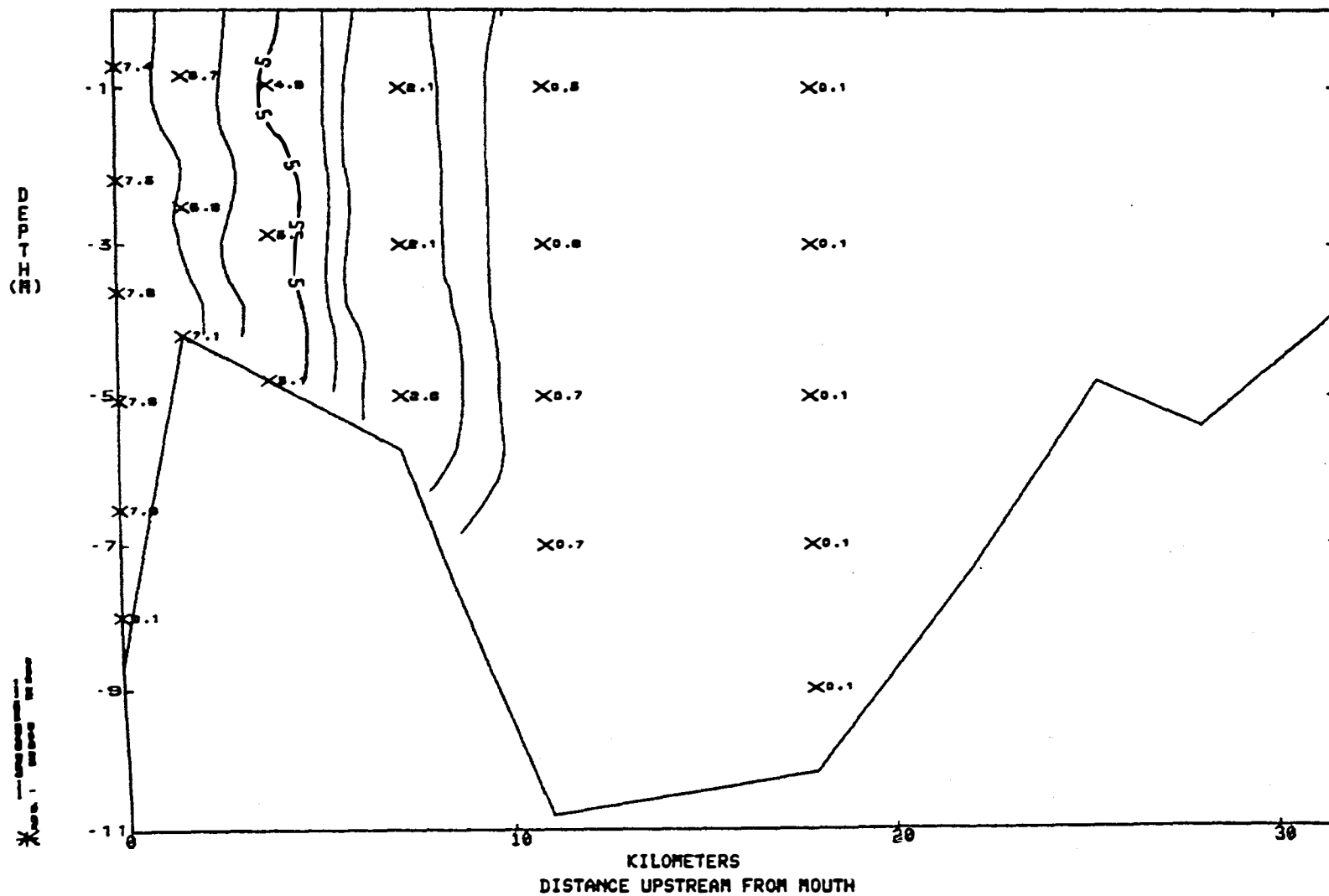


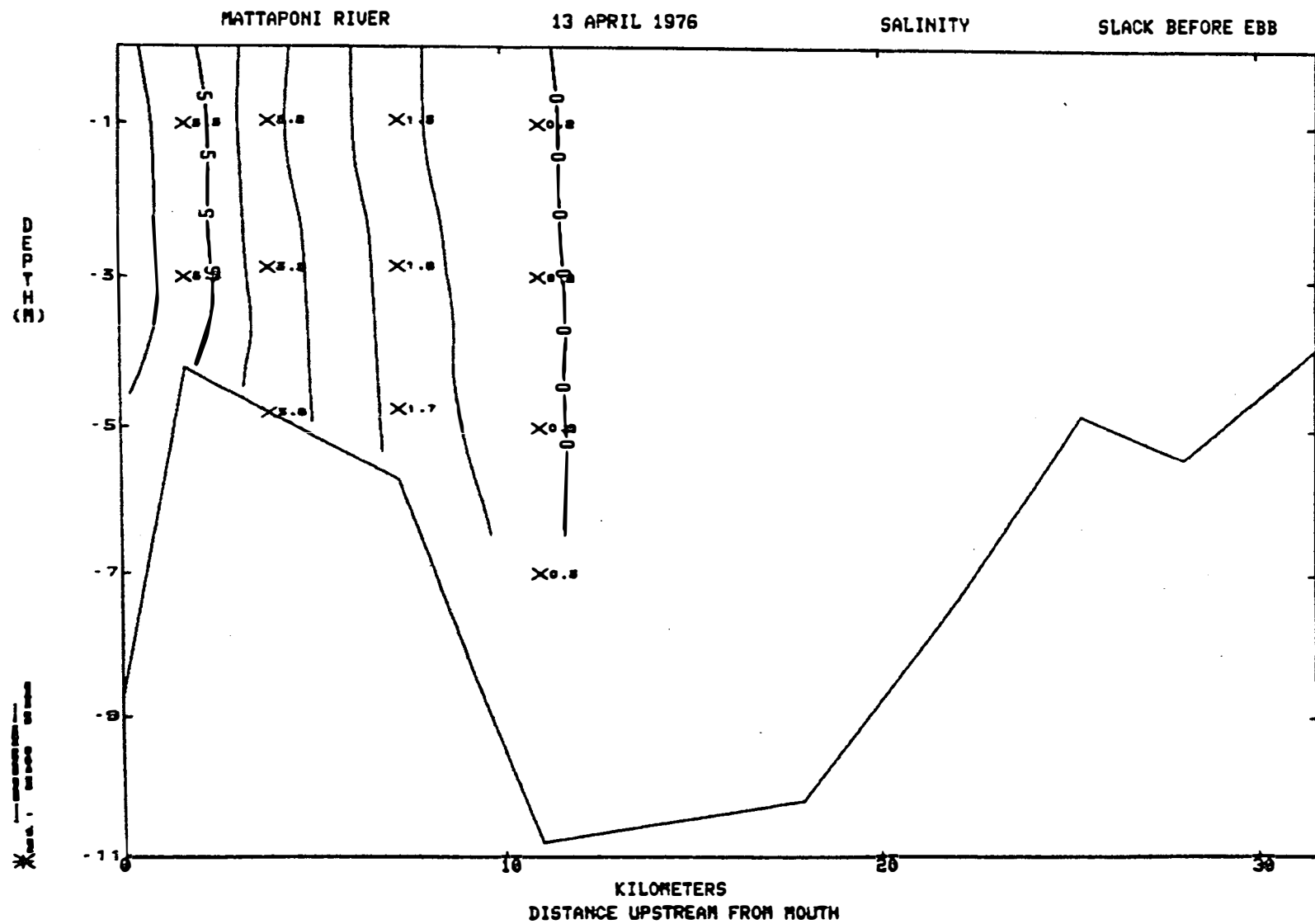
MATTAPONI RIVER

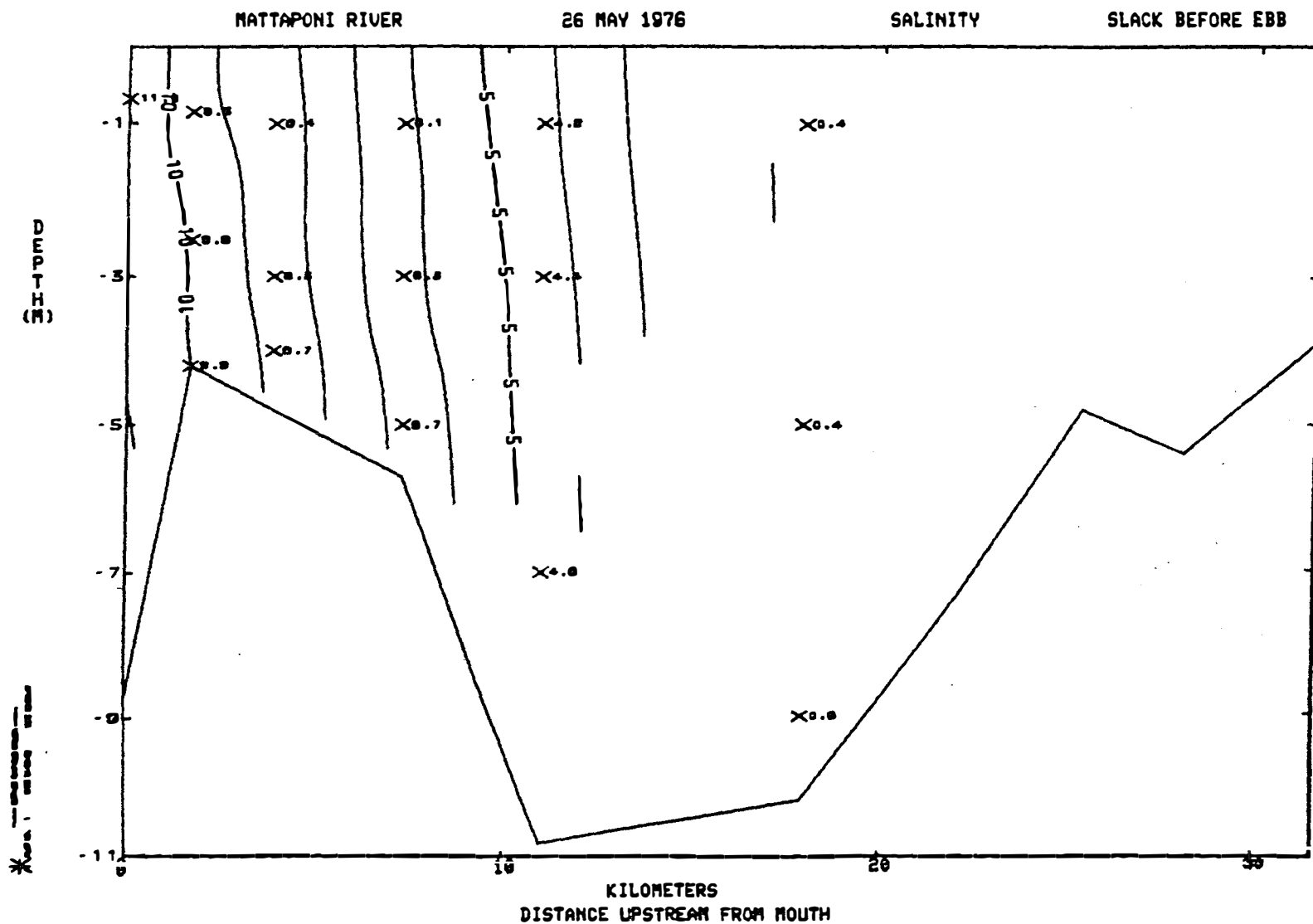
18 NOVEMBER 1975

SALINITY

SLACK BEFORE EBB





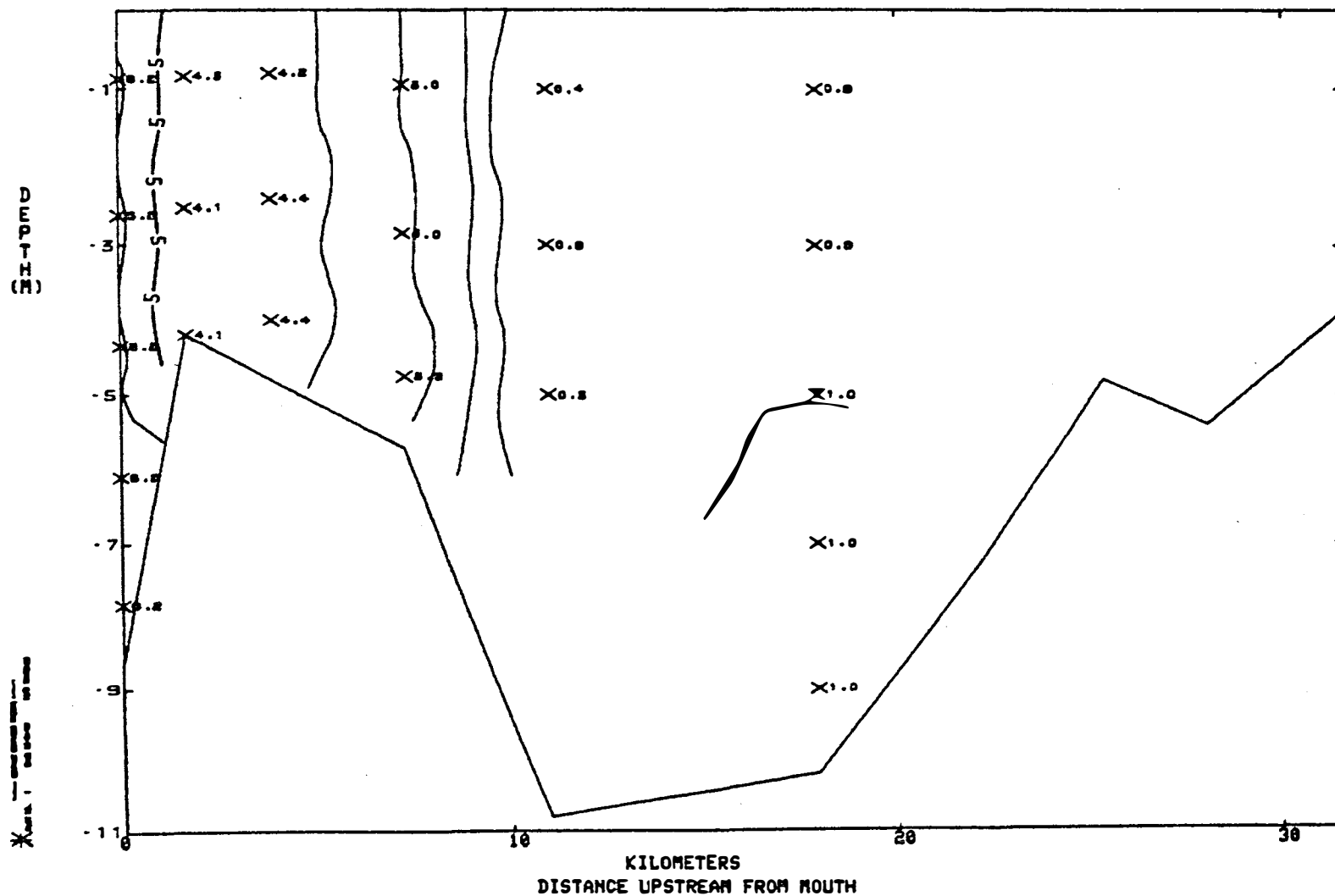


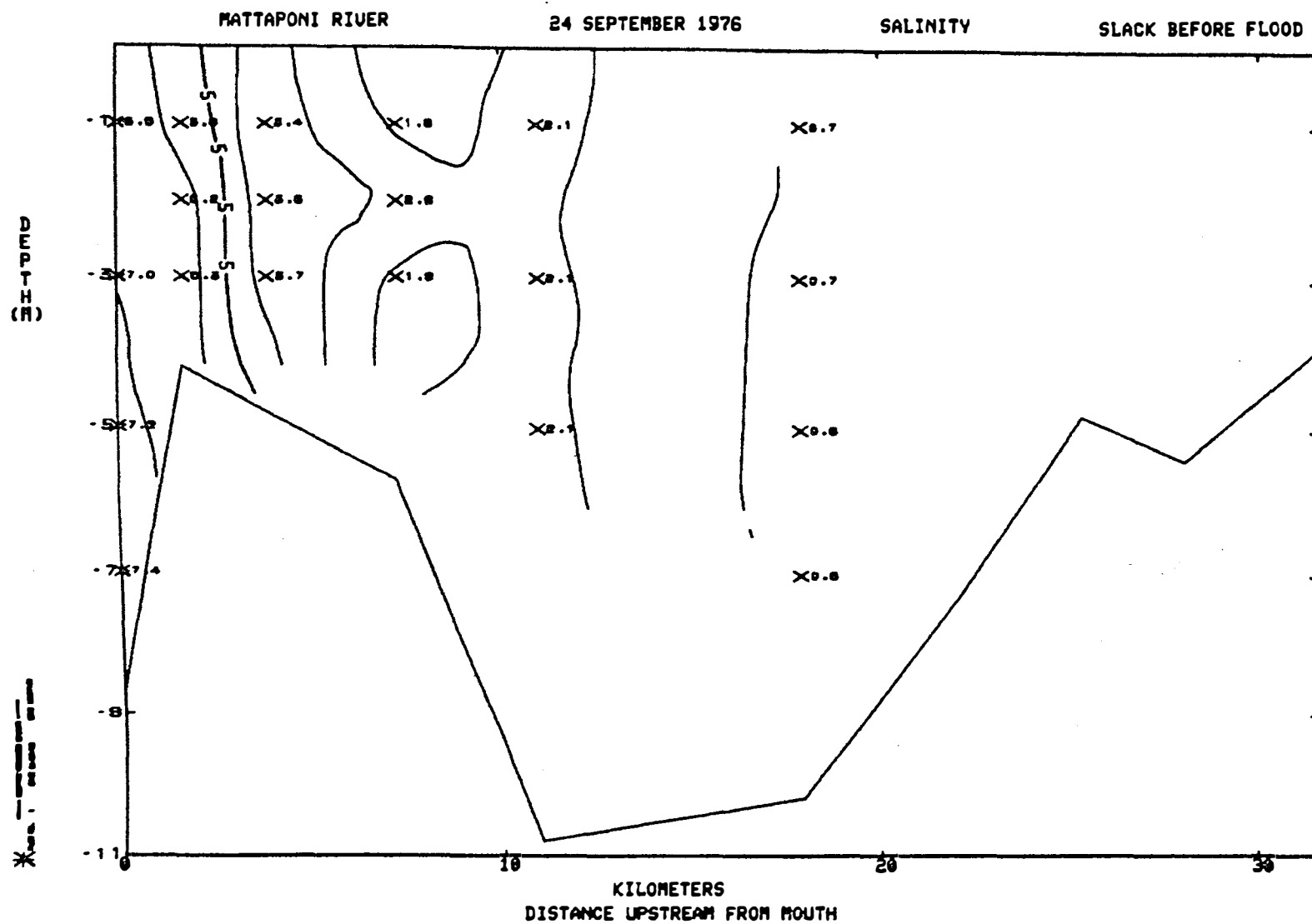
MATTAPONI RIVER

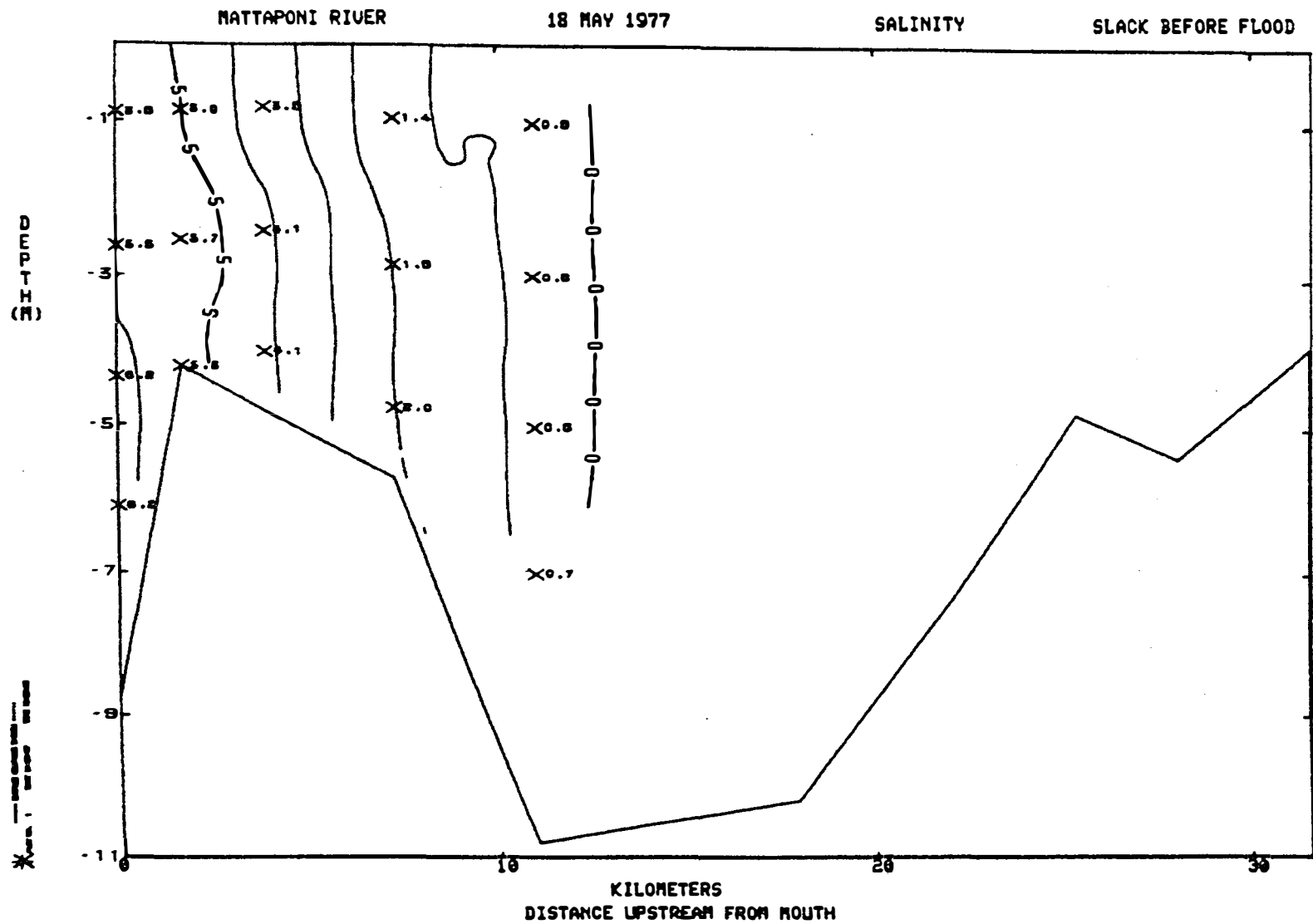
09 JUNE 1976

SALINITY

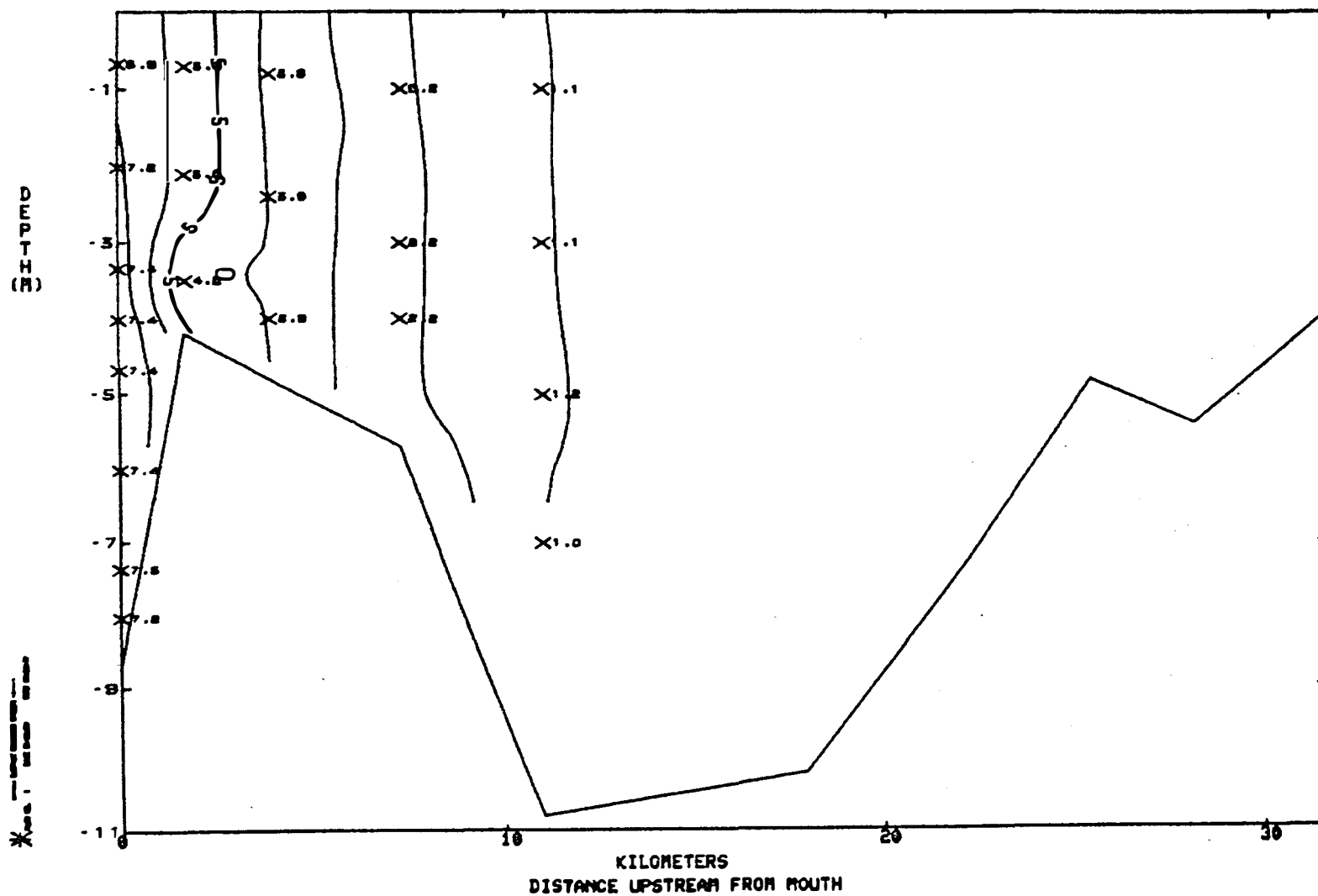
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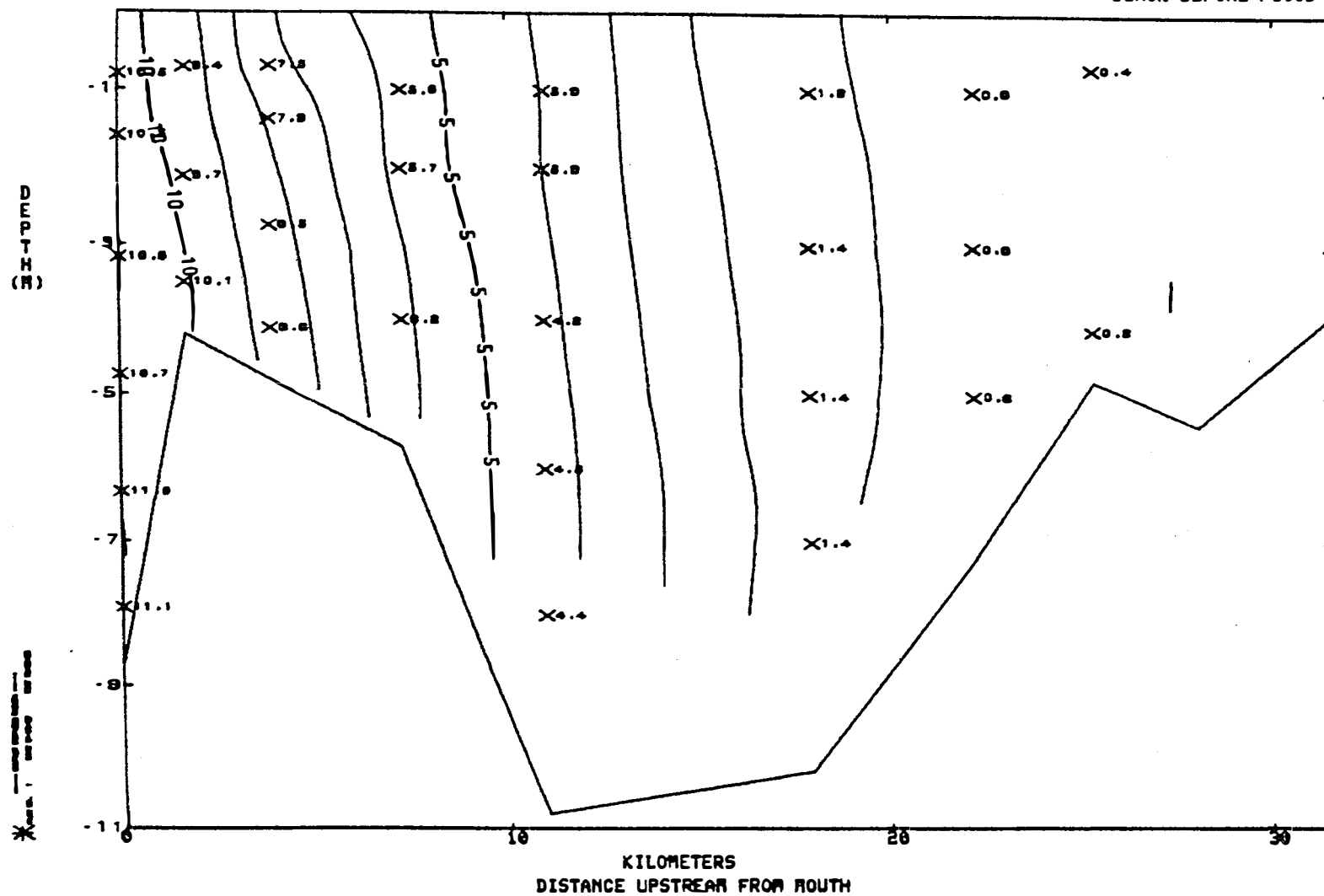


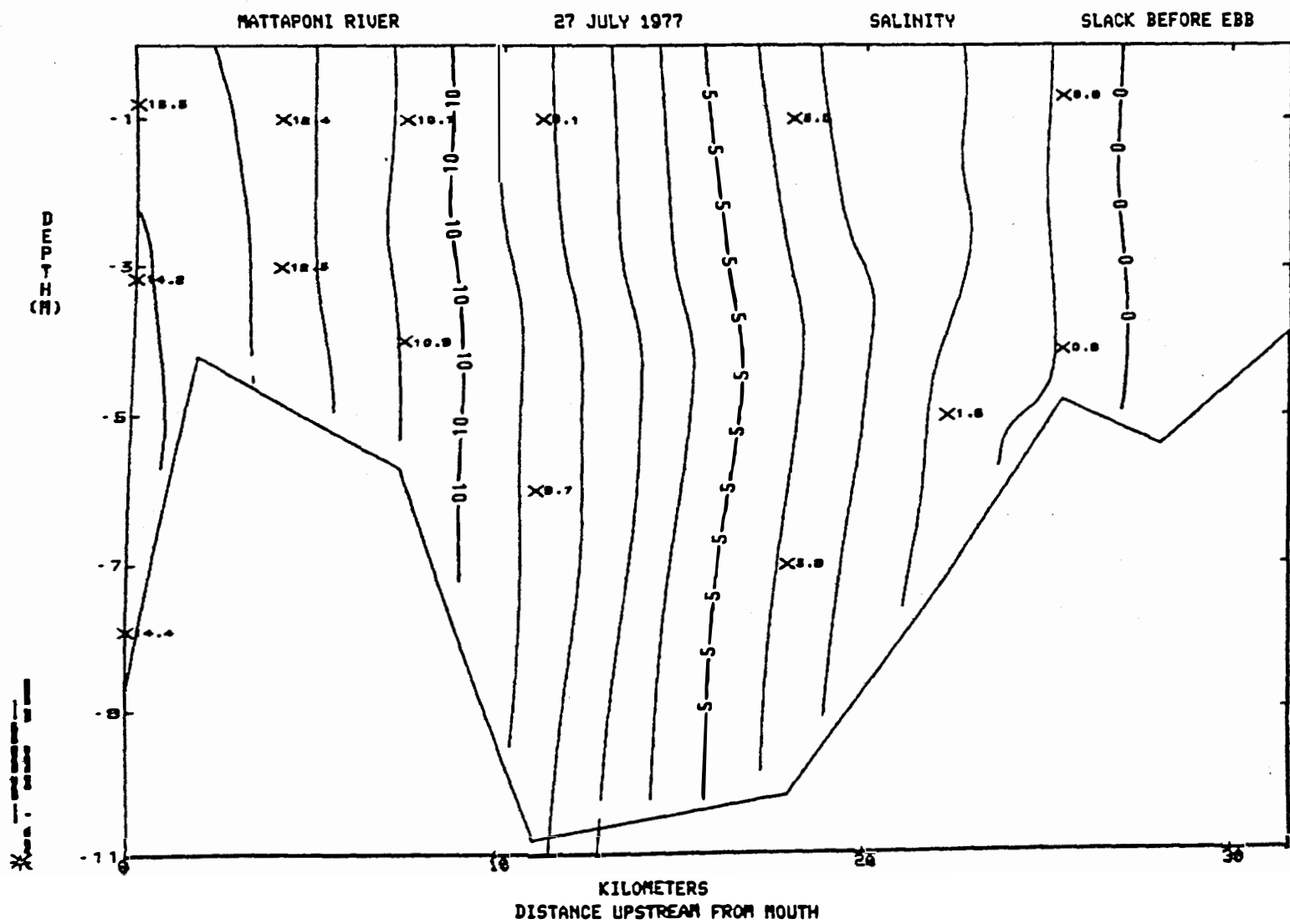


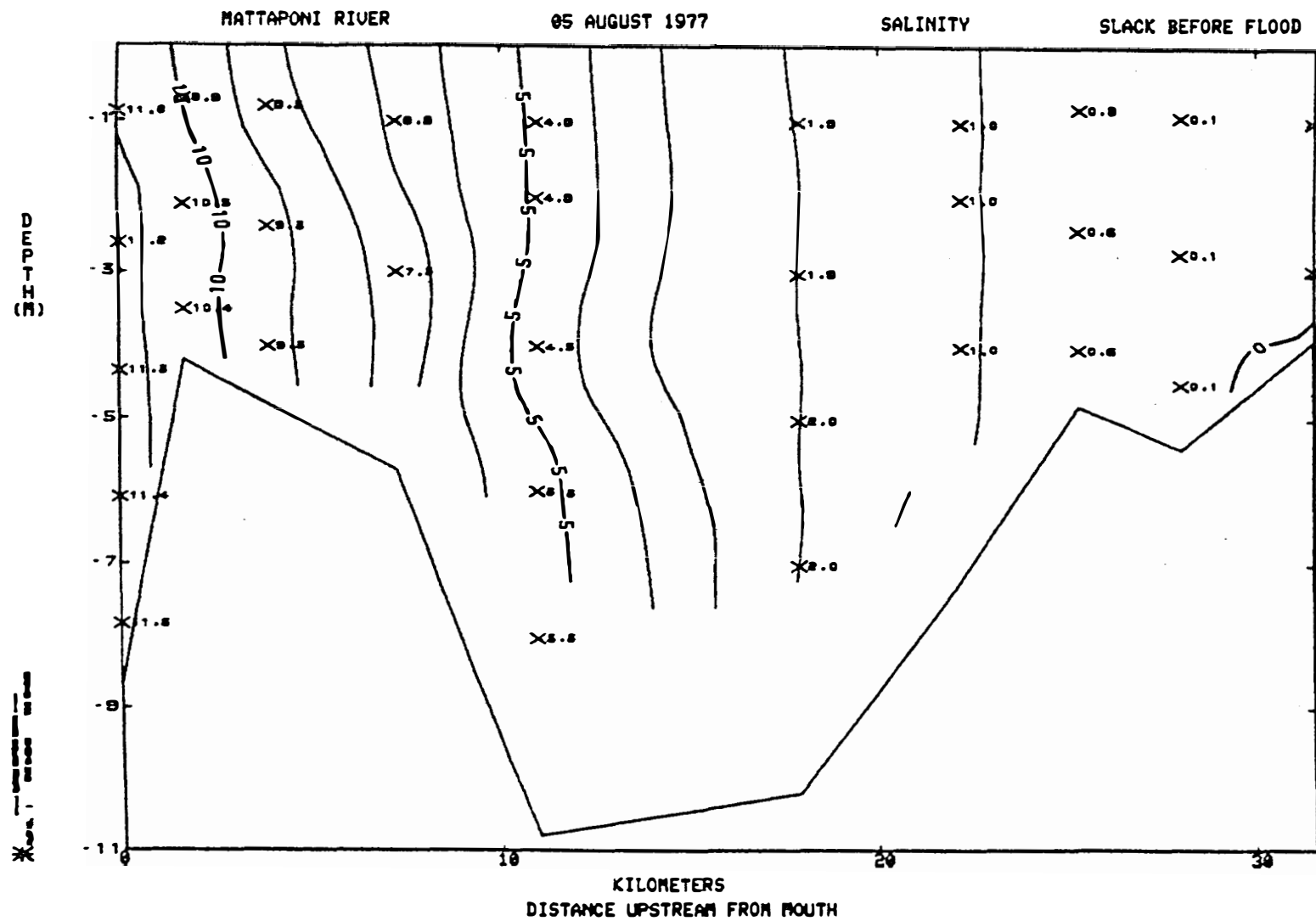
SLACK BEFORE FLOOD



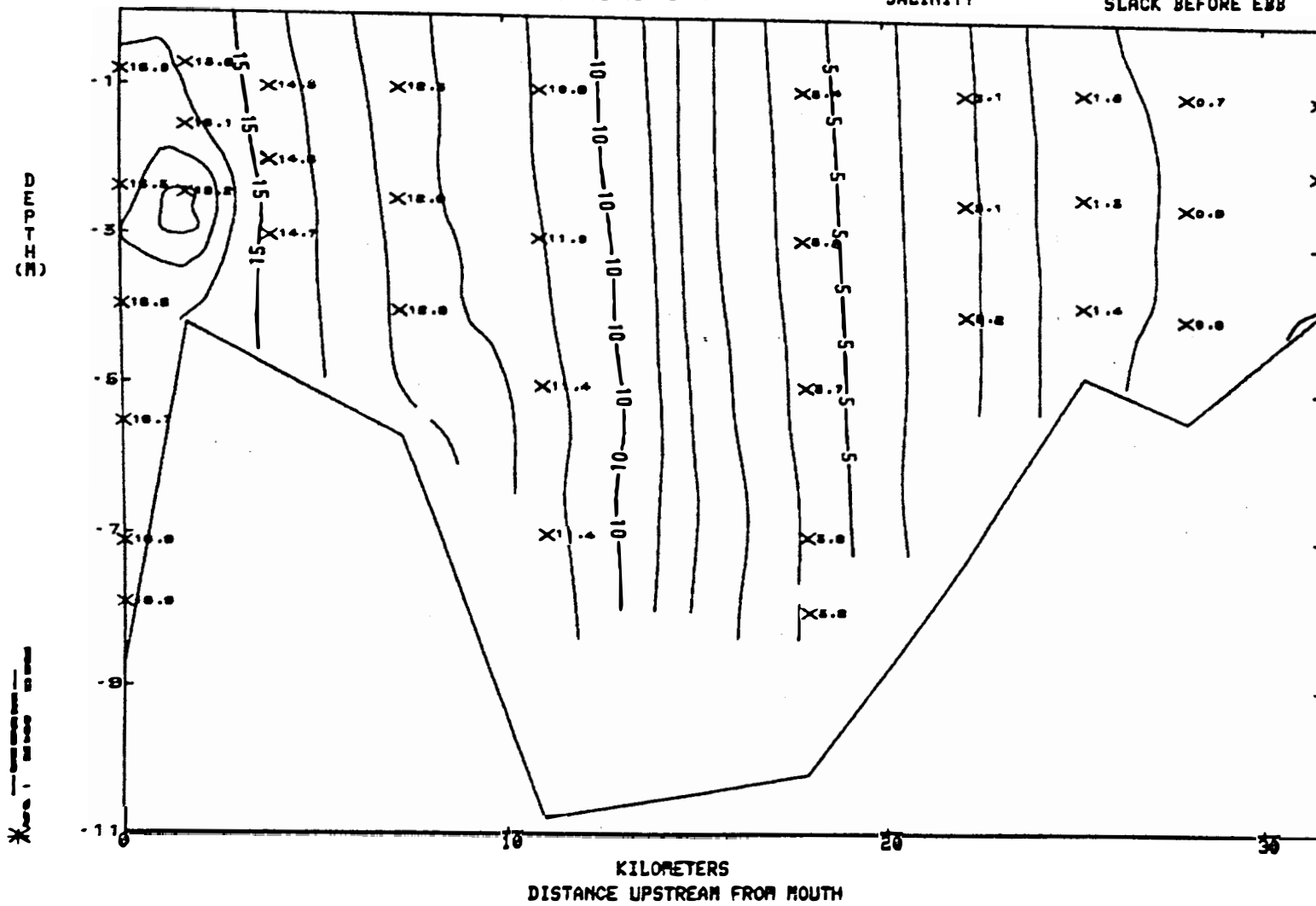
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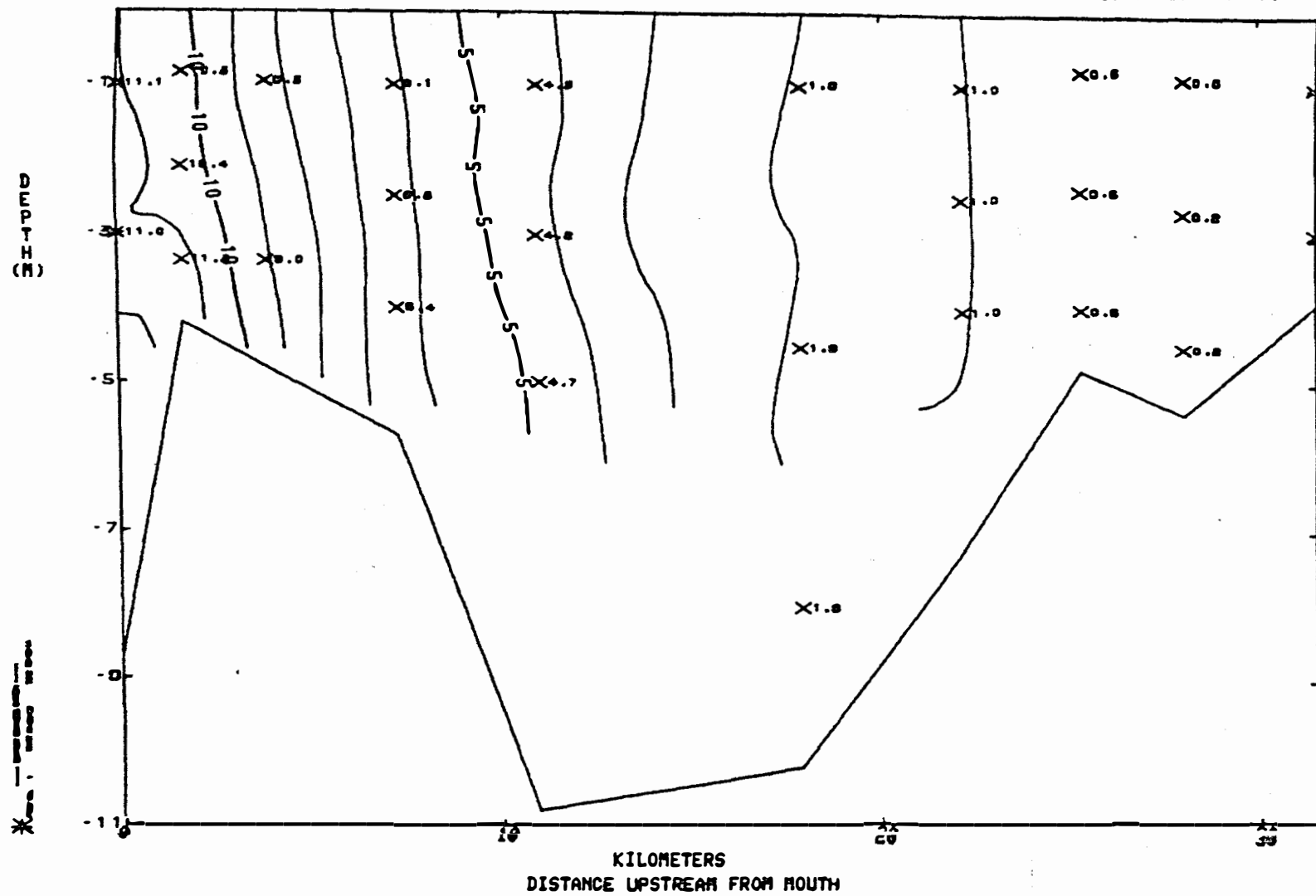


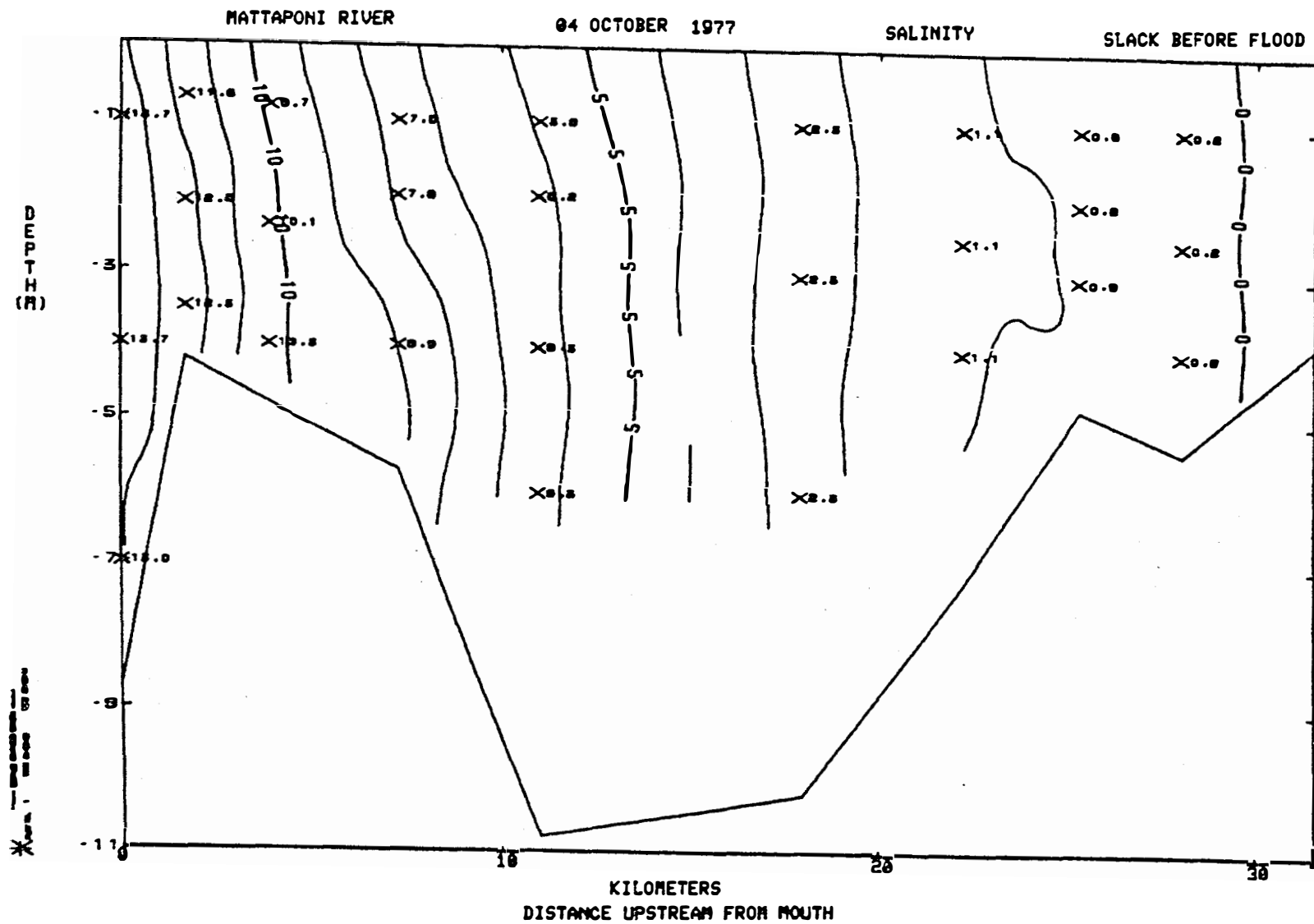


SLACK BEFORE EBB



SLACK BEFORE FLOOD



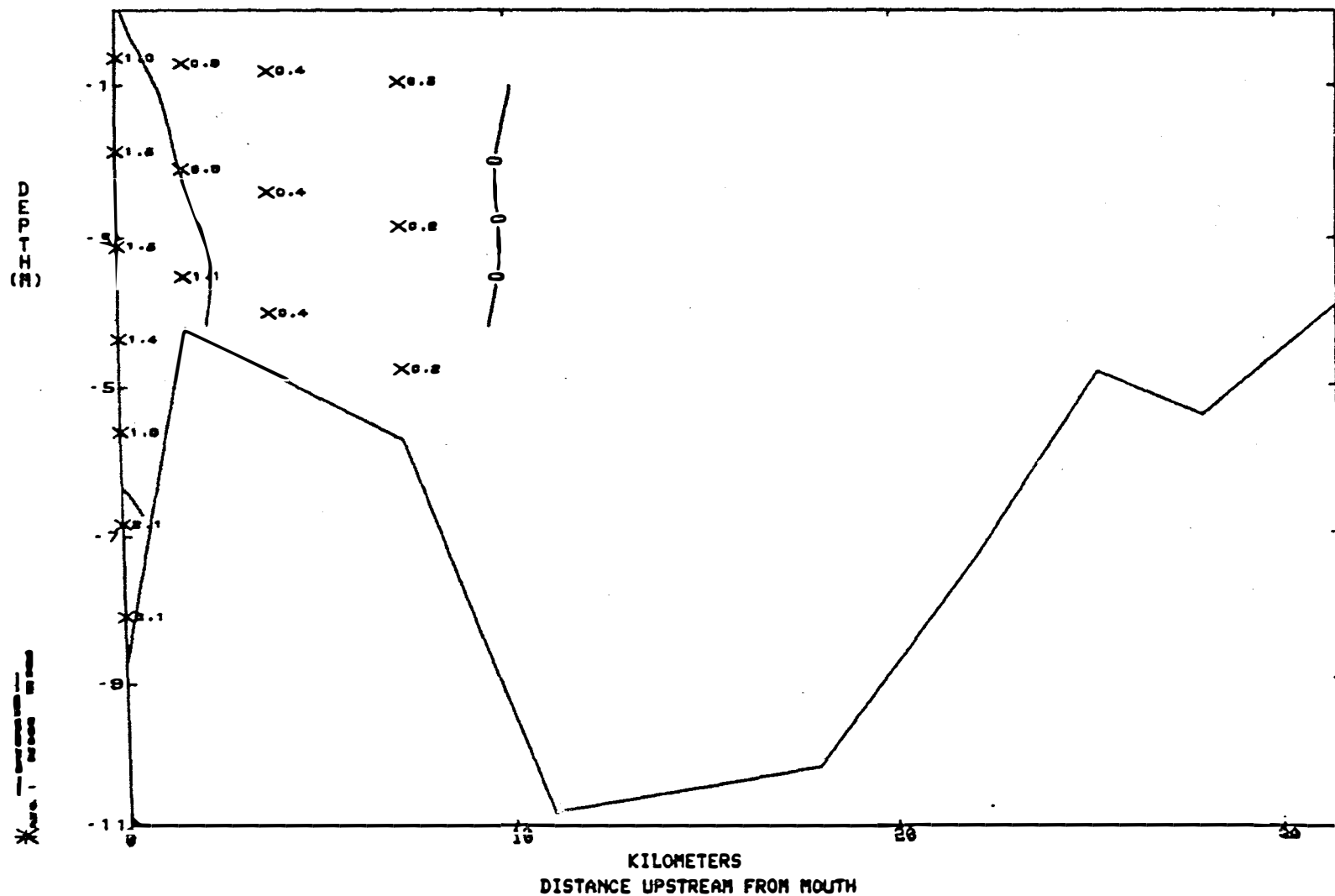


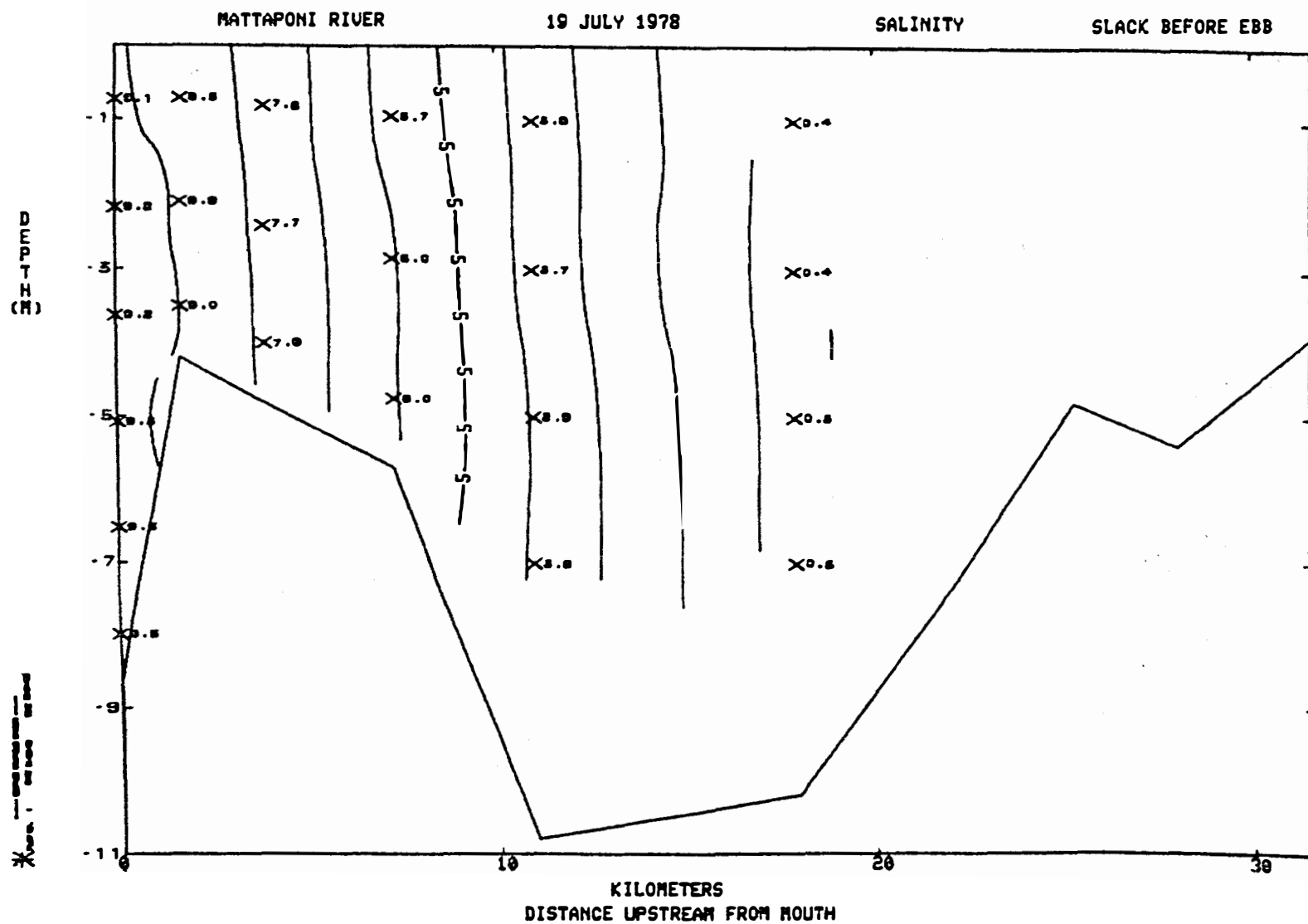
MATTAPONI RIVER

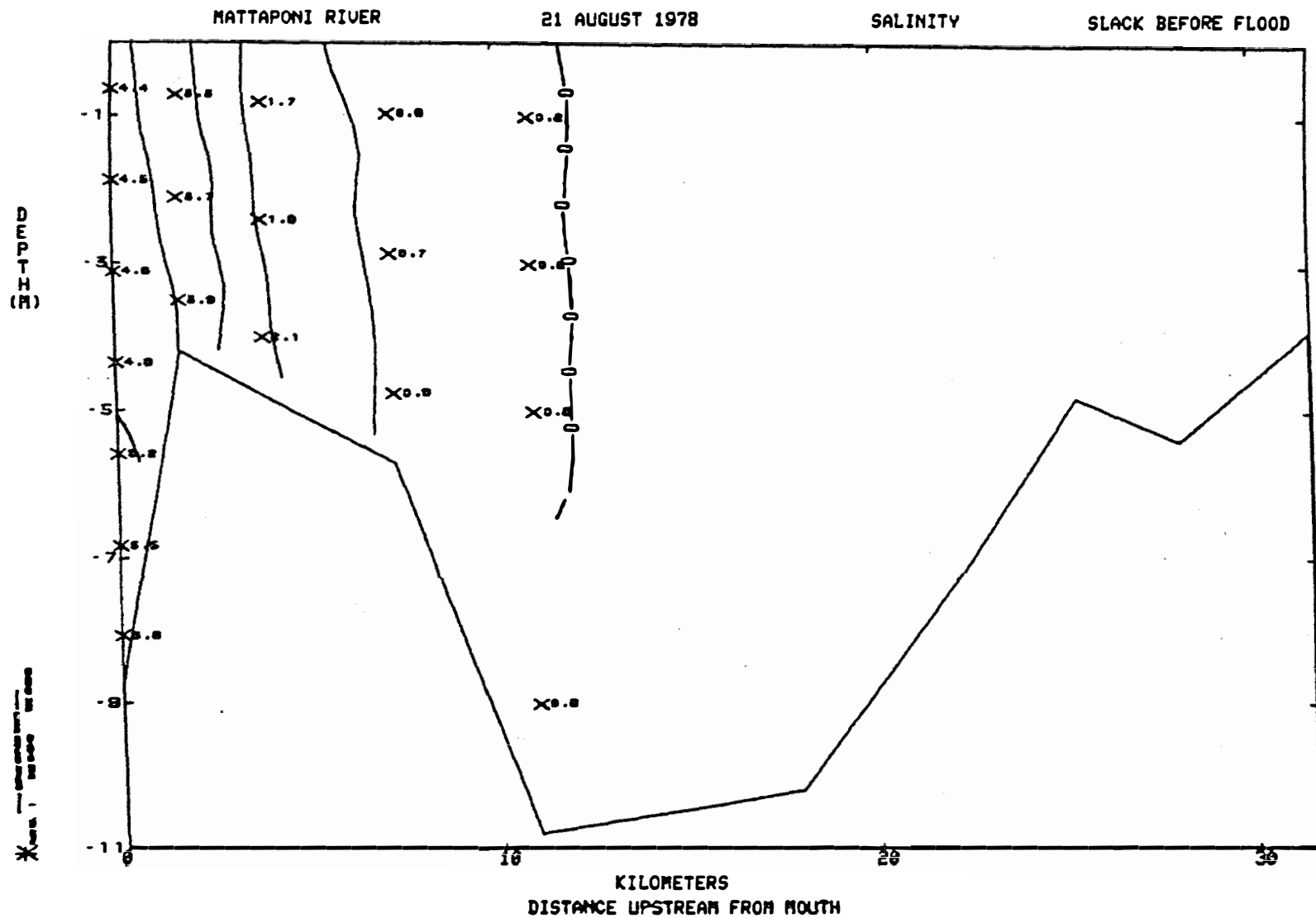
12 JUNE 1978

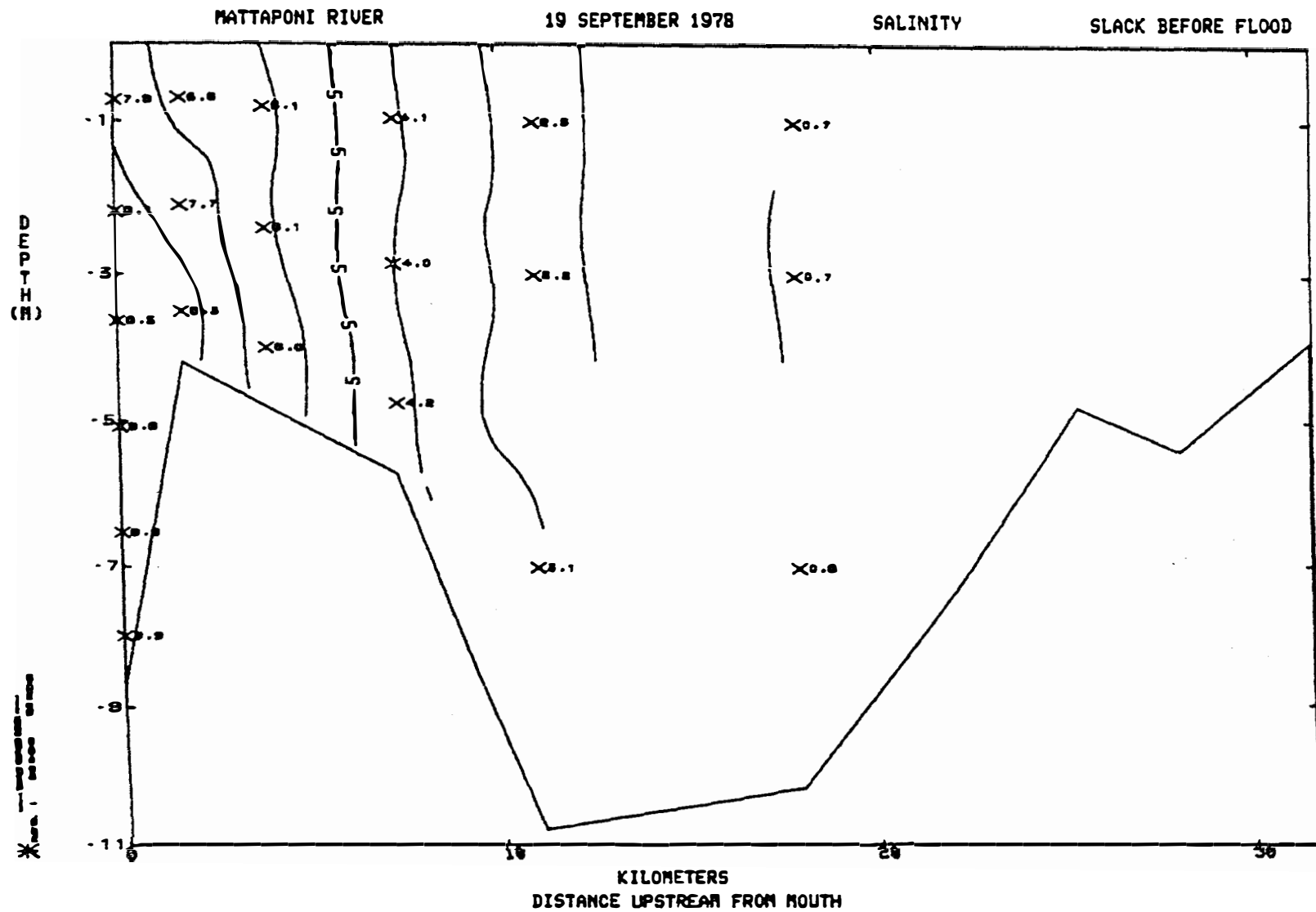
SALINITY

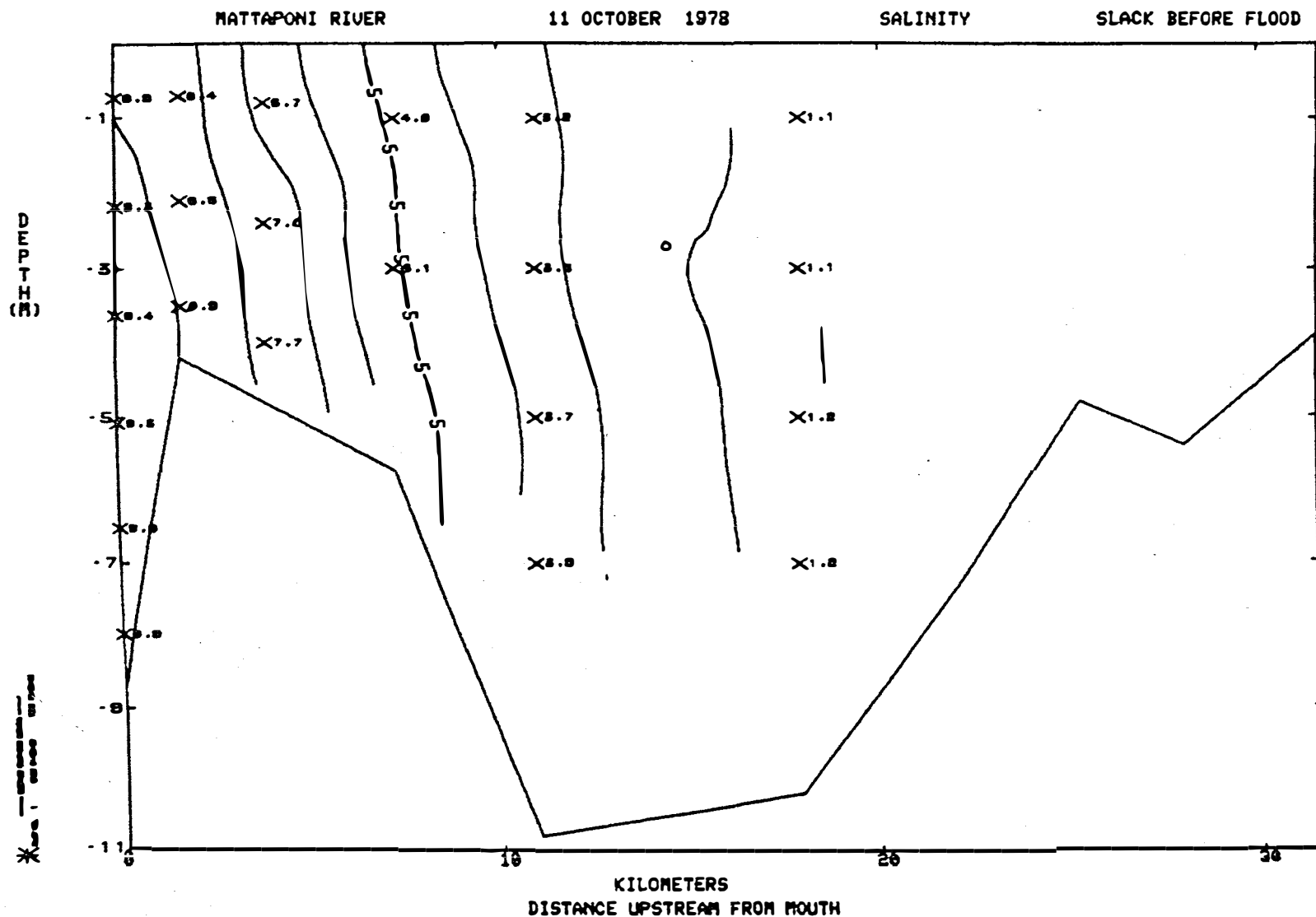
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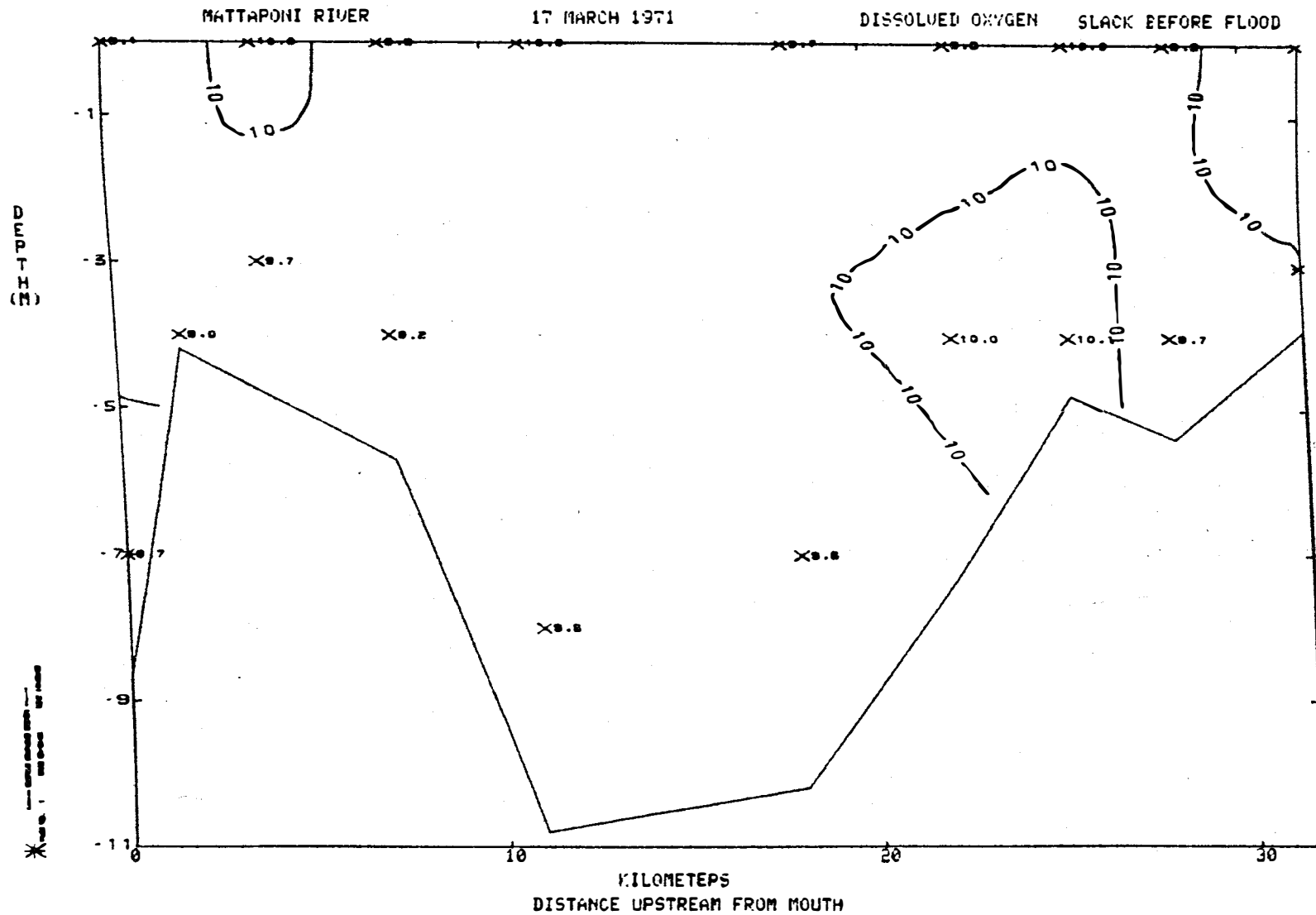


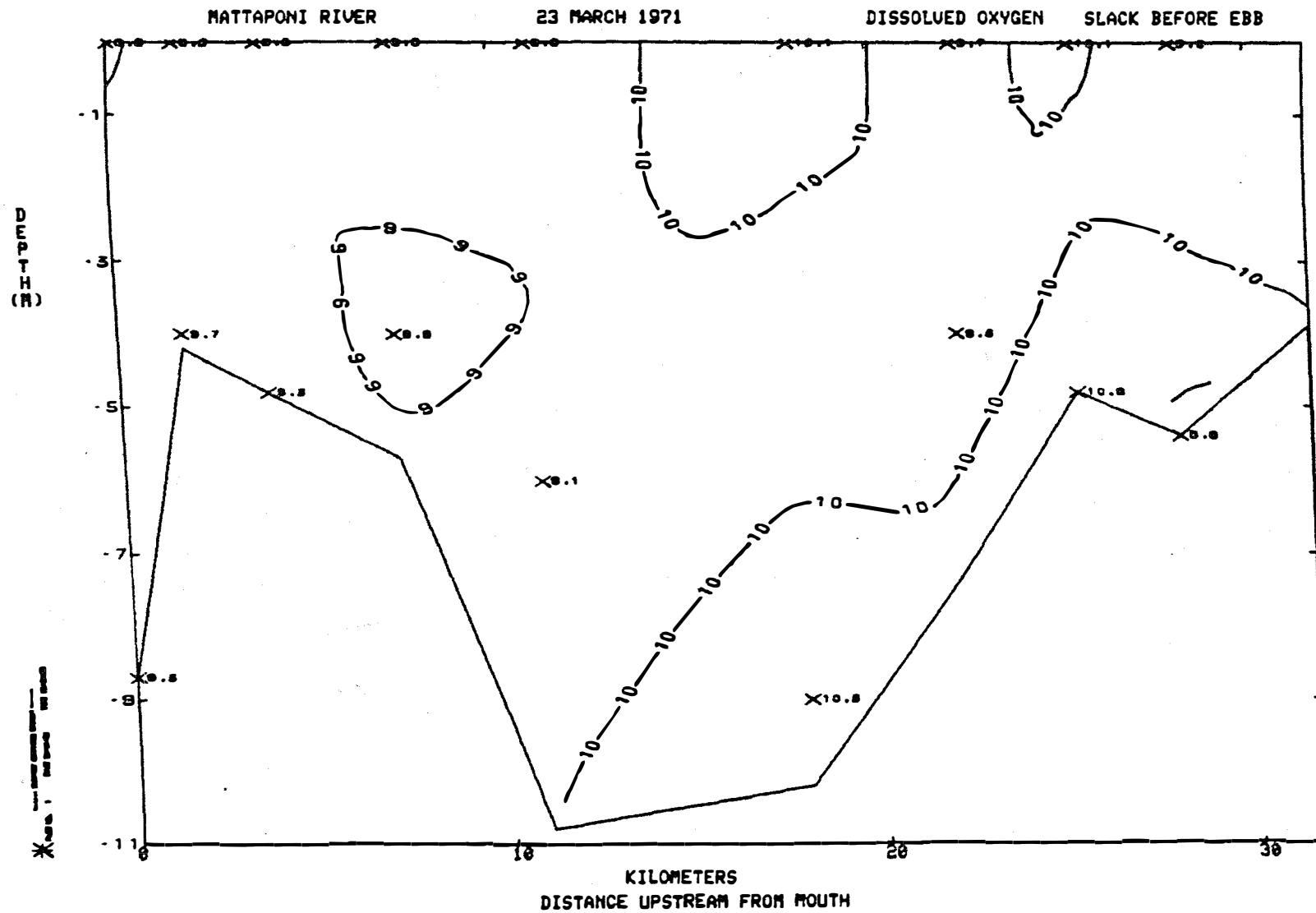


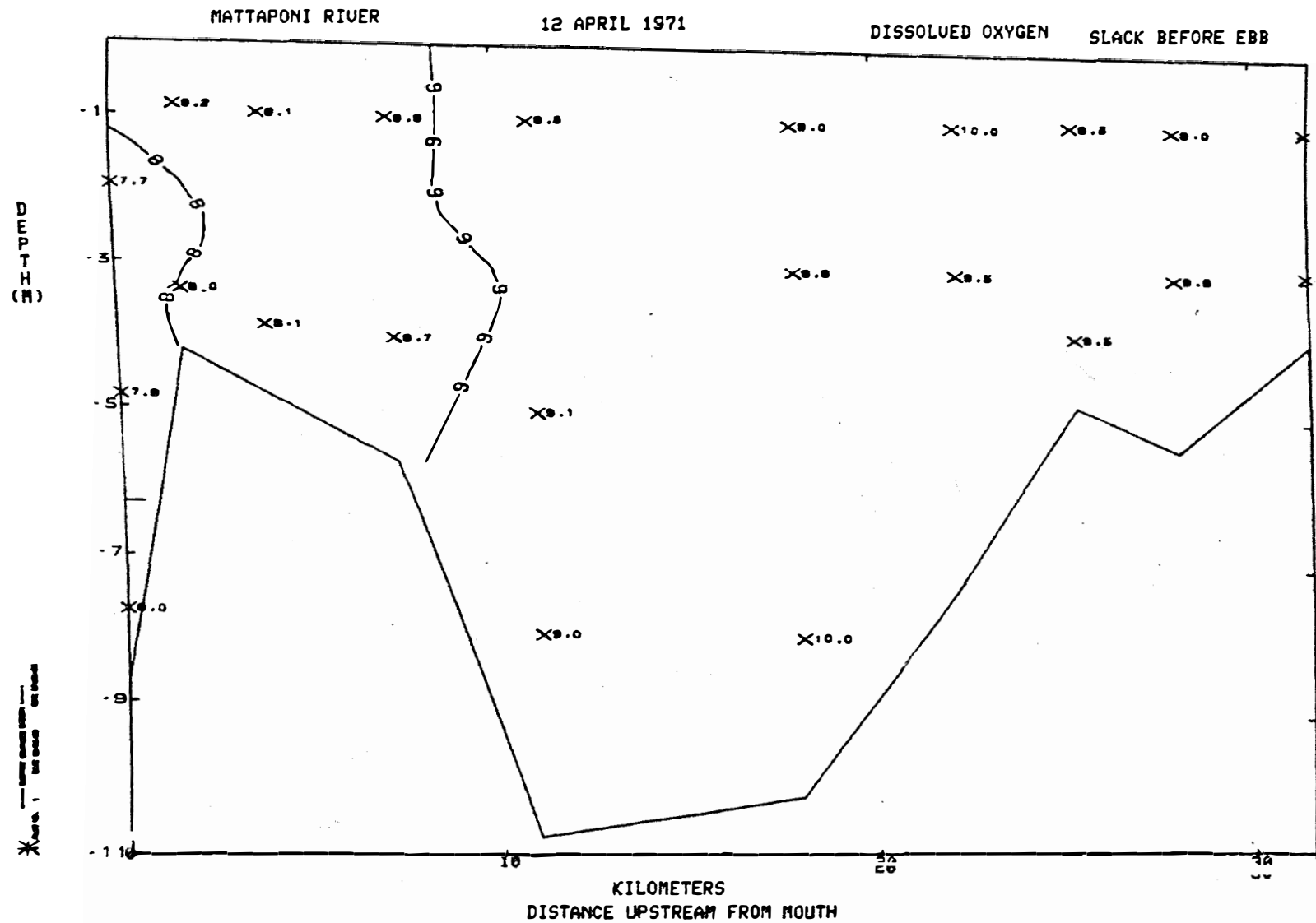


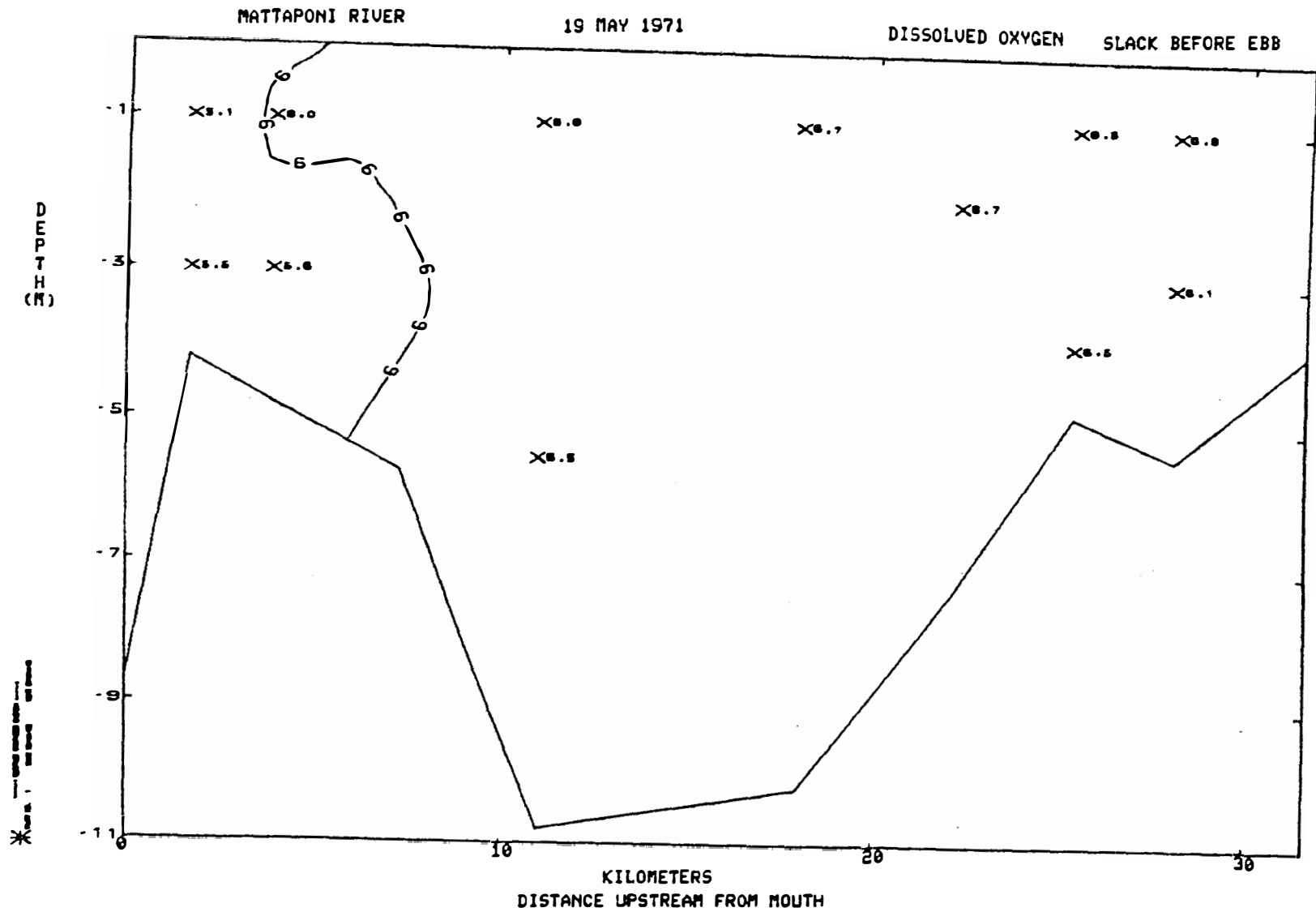


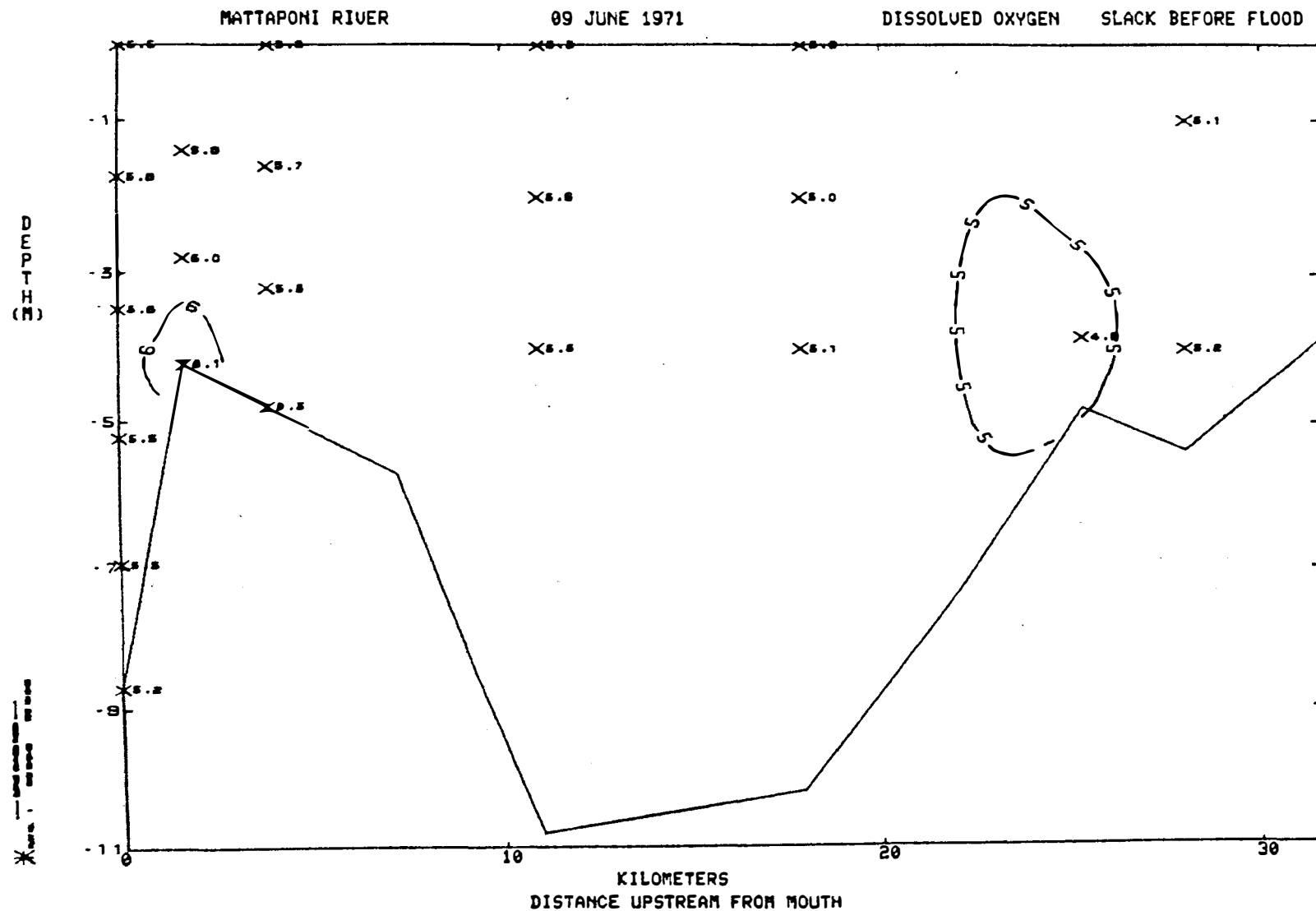
D. Dissolved Oxygen (mg/l)

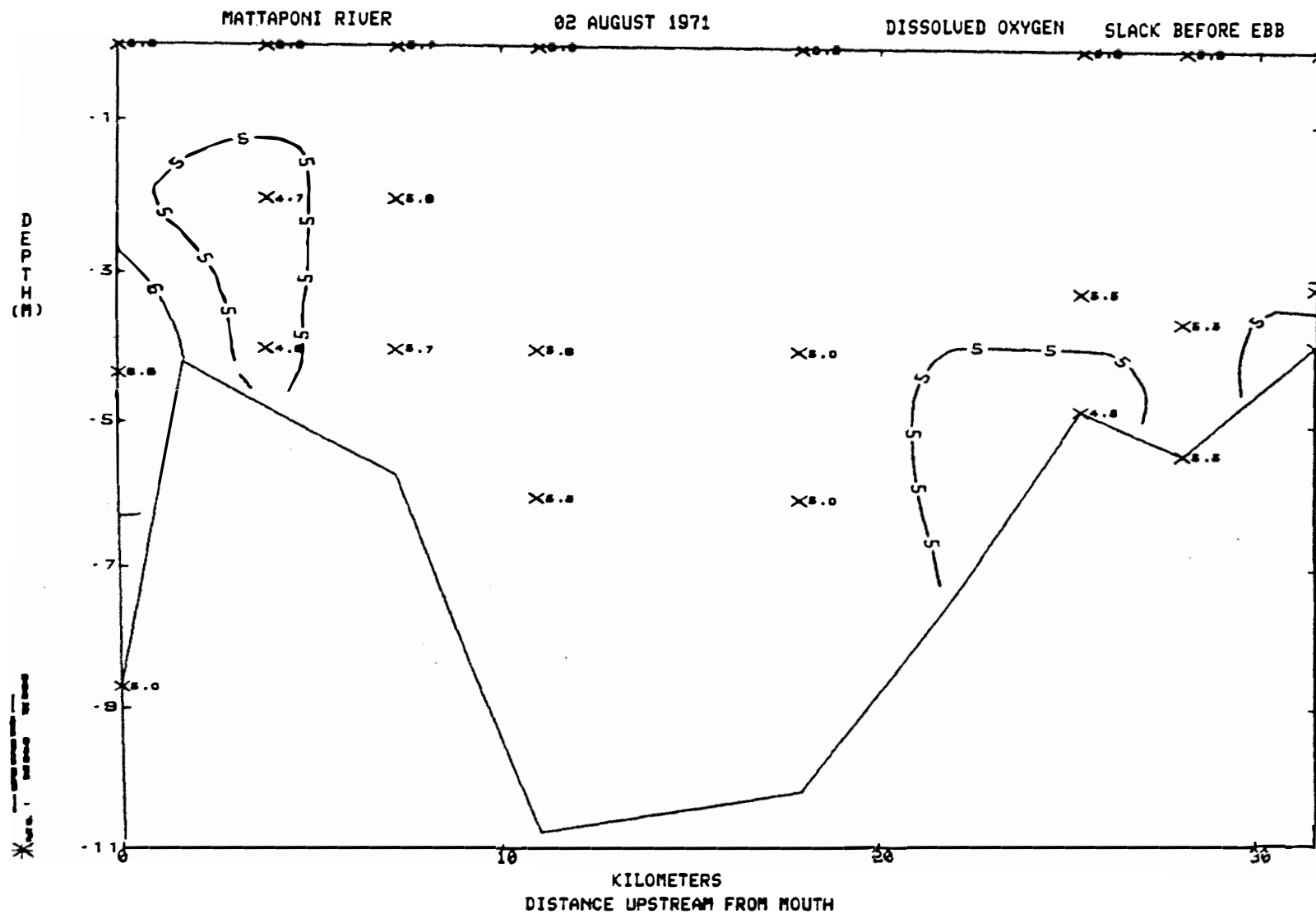


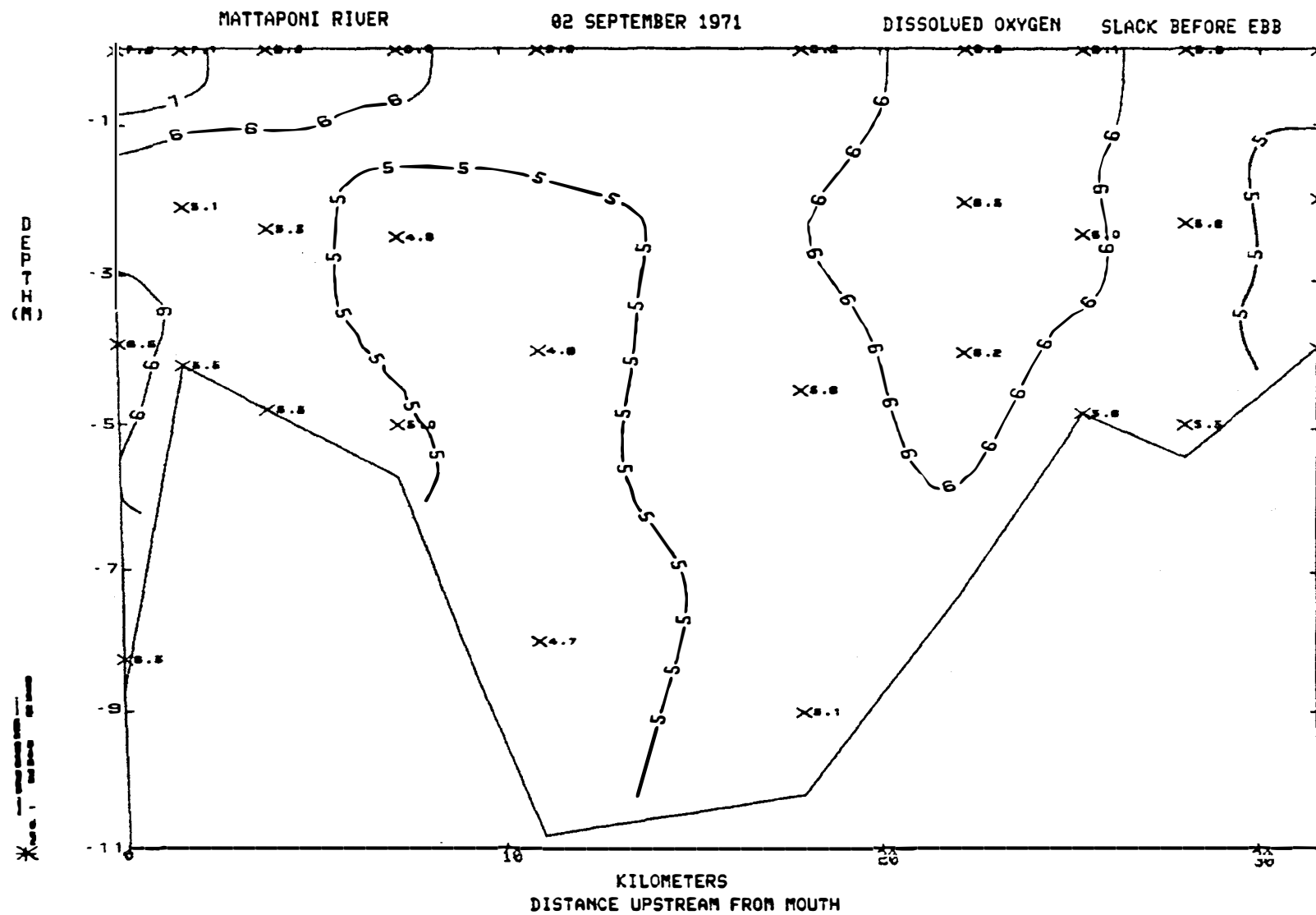


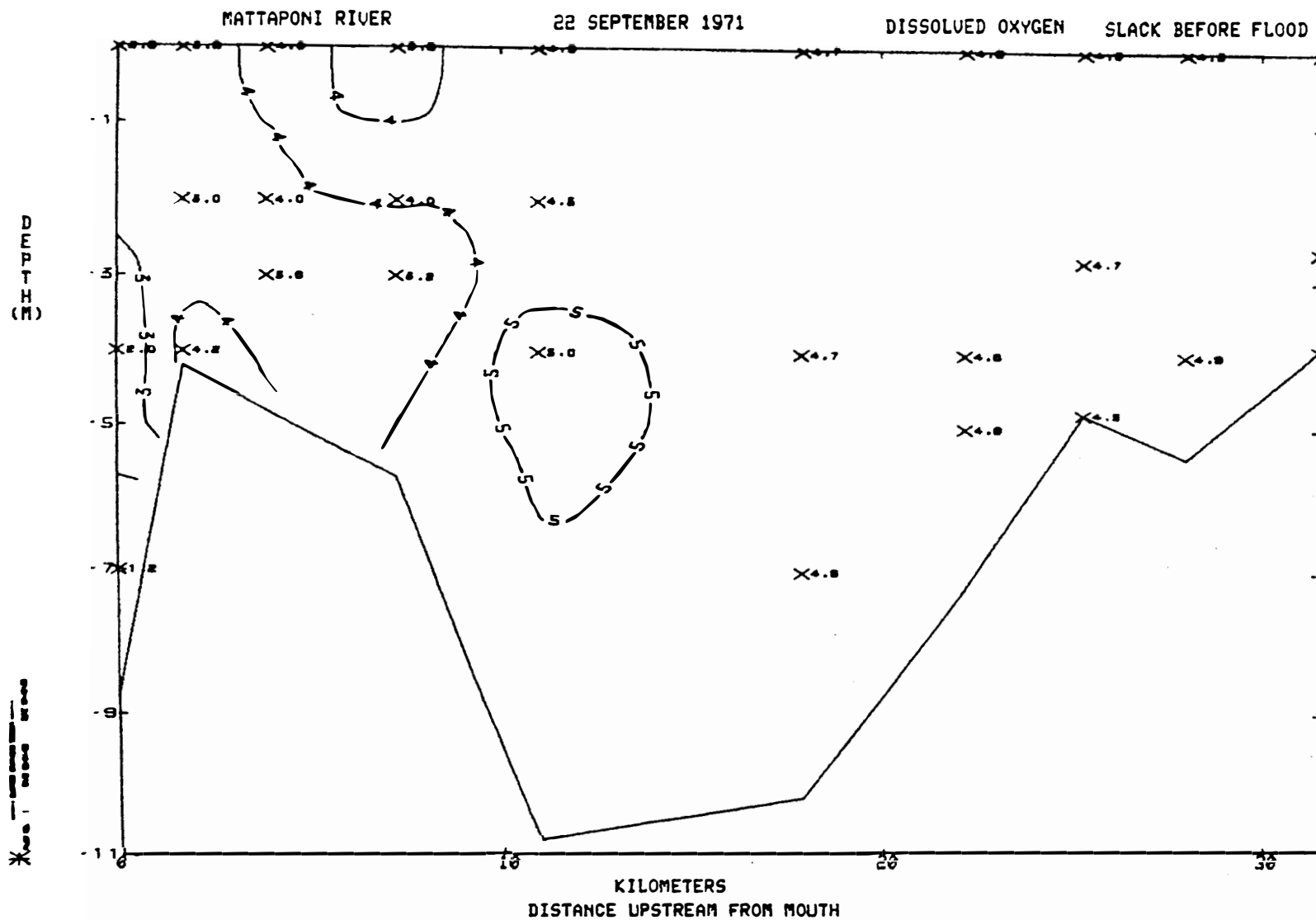


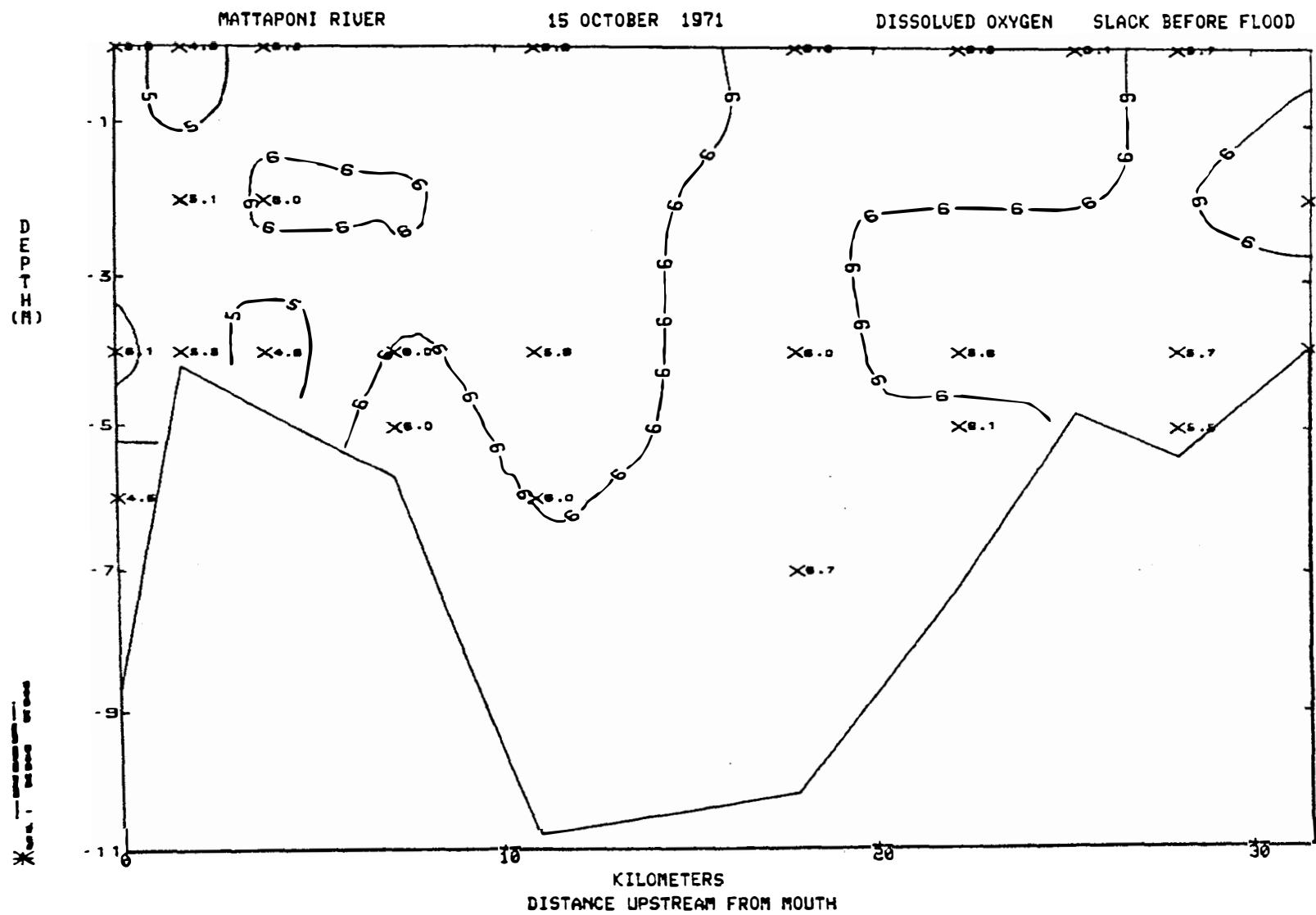


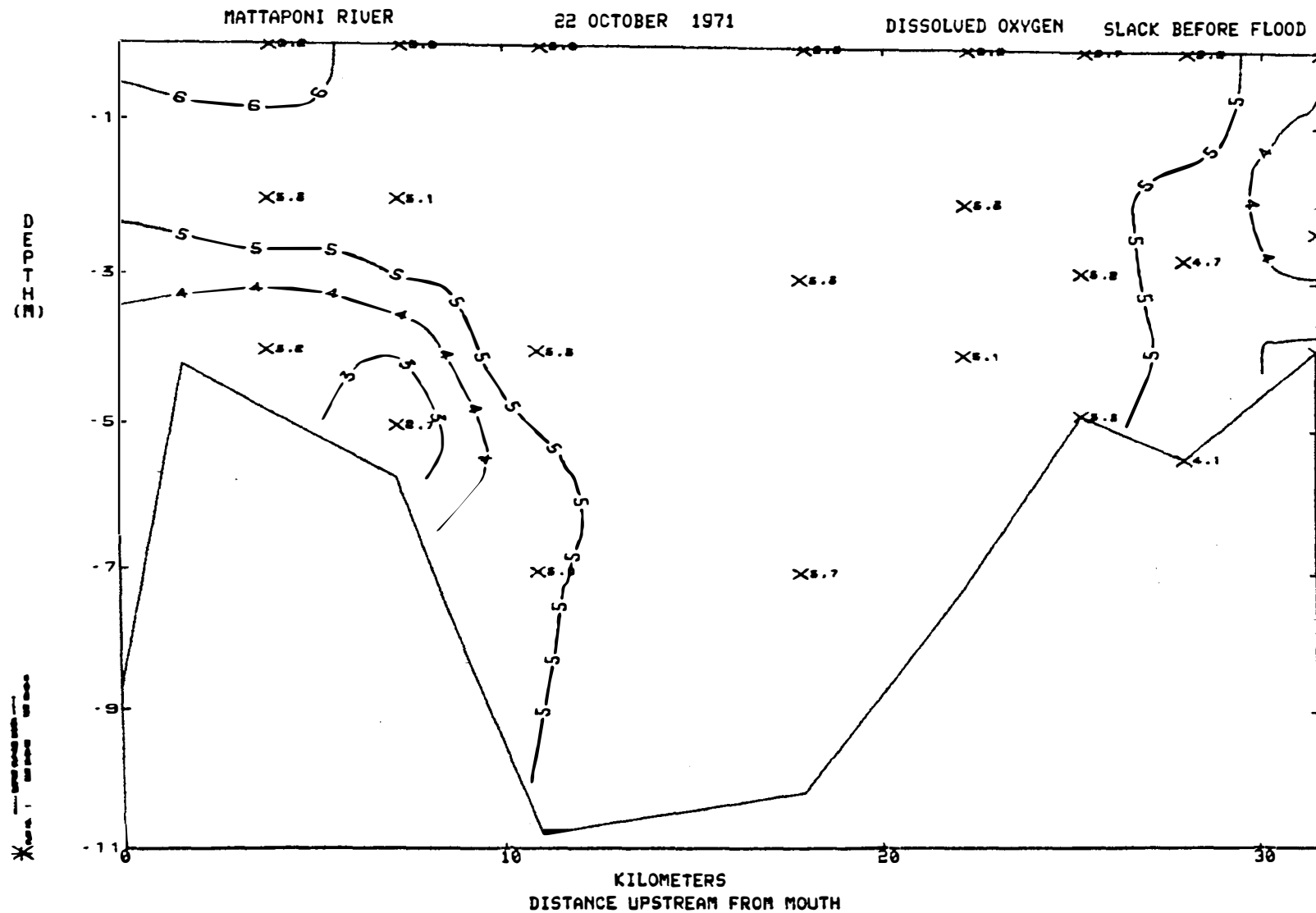


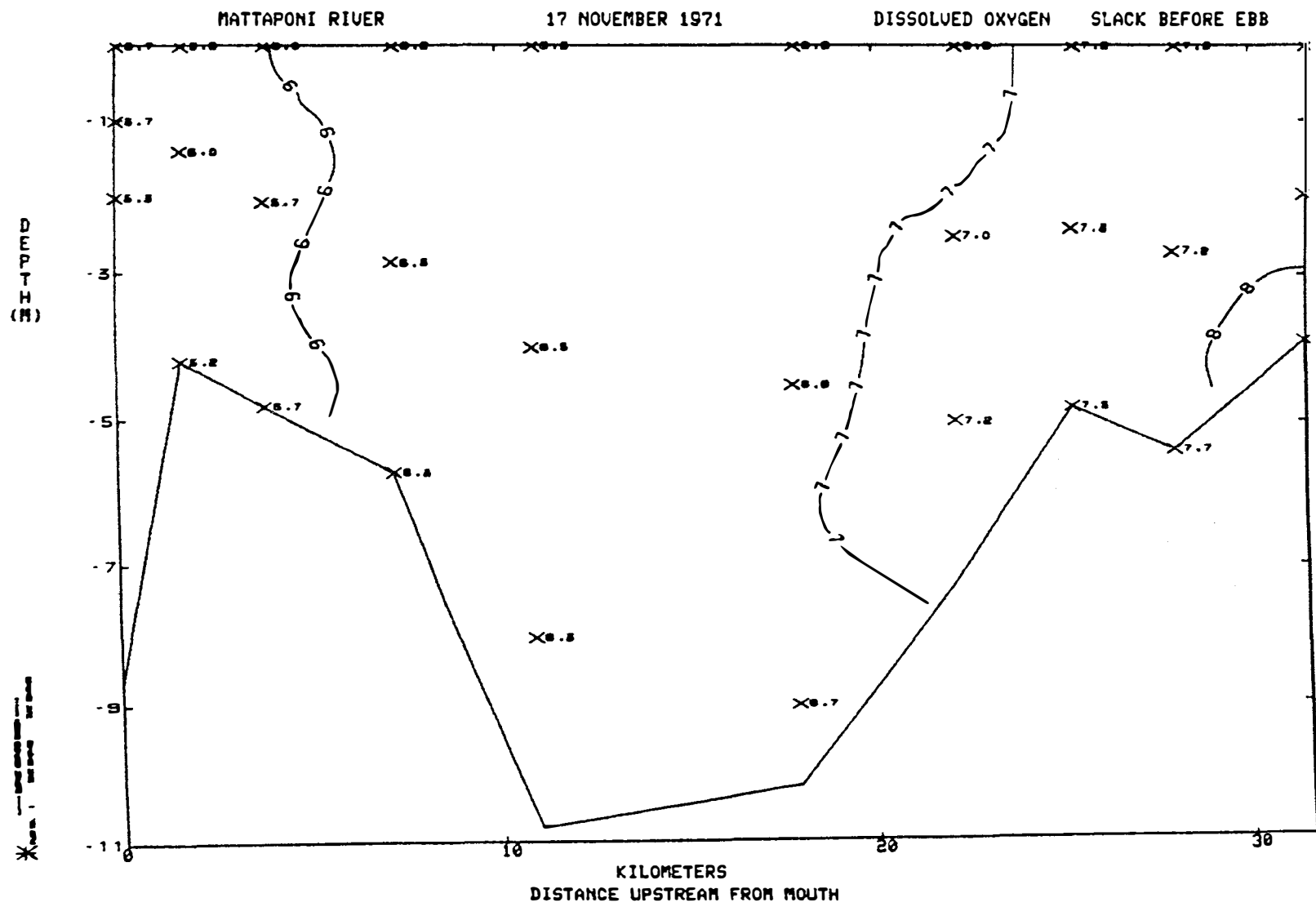


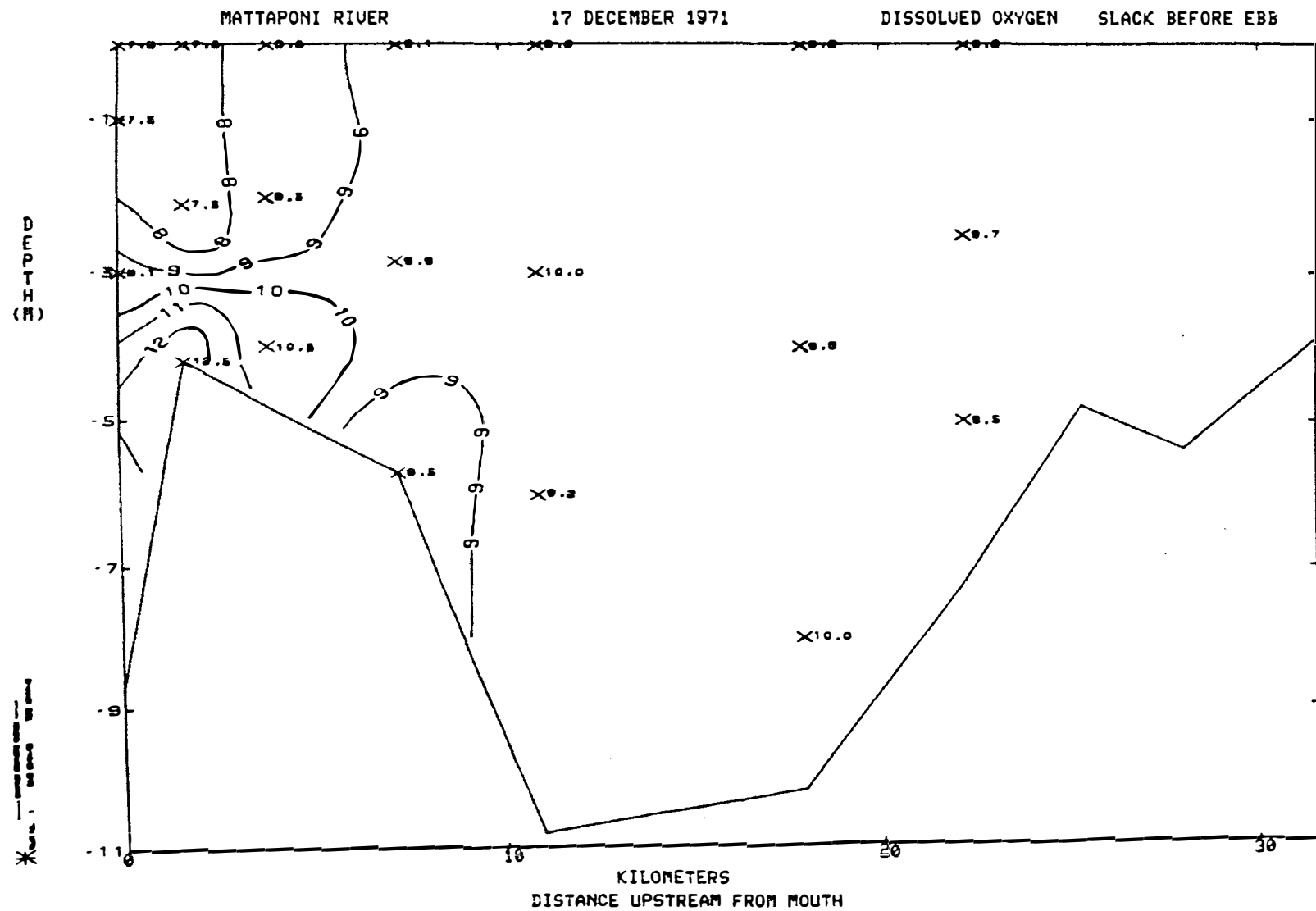


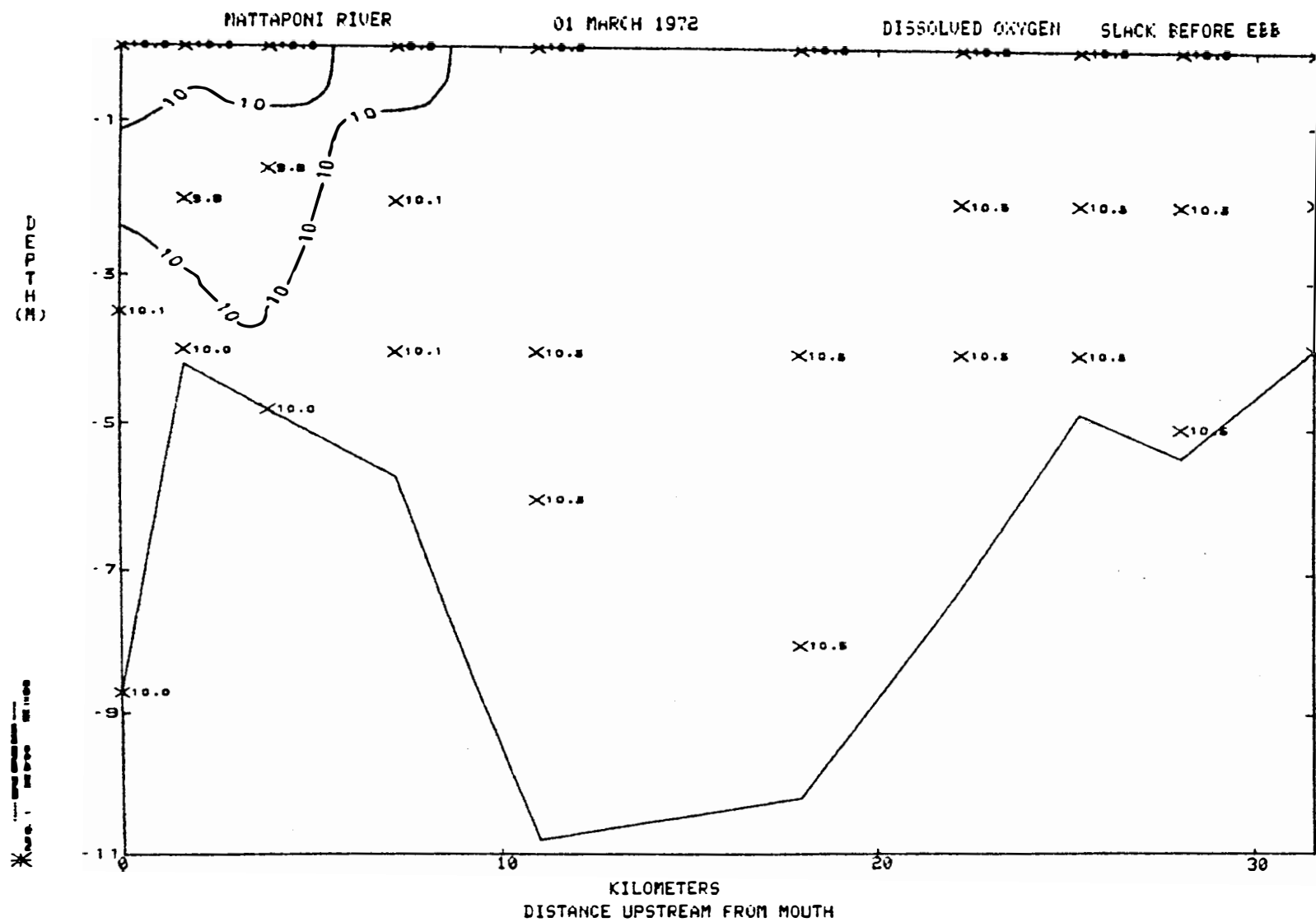


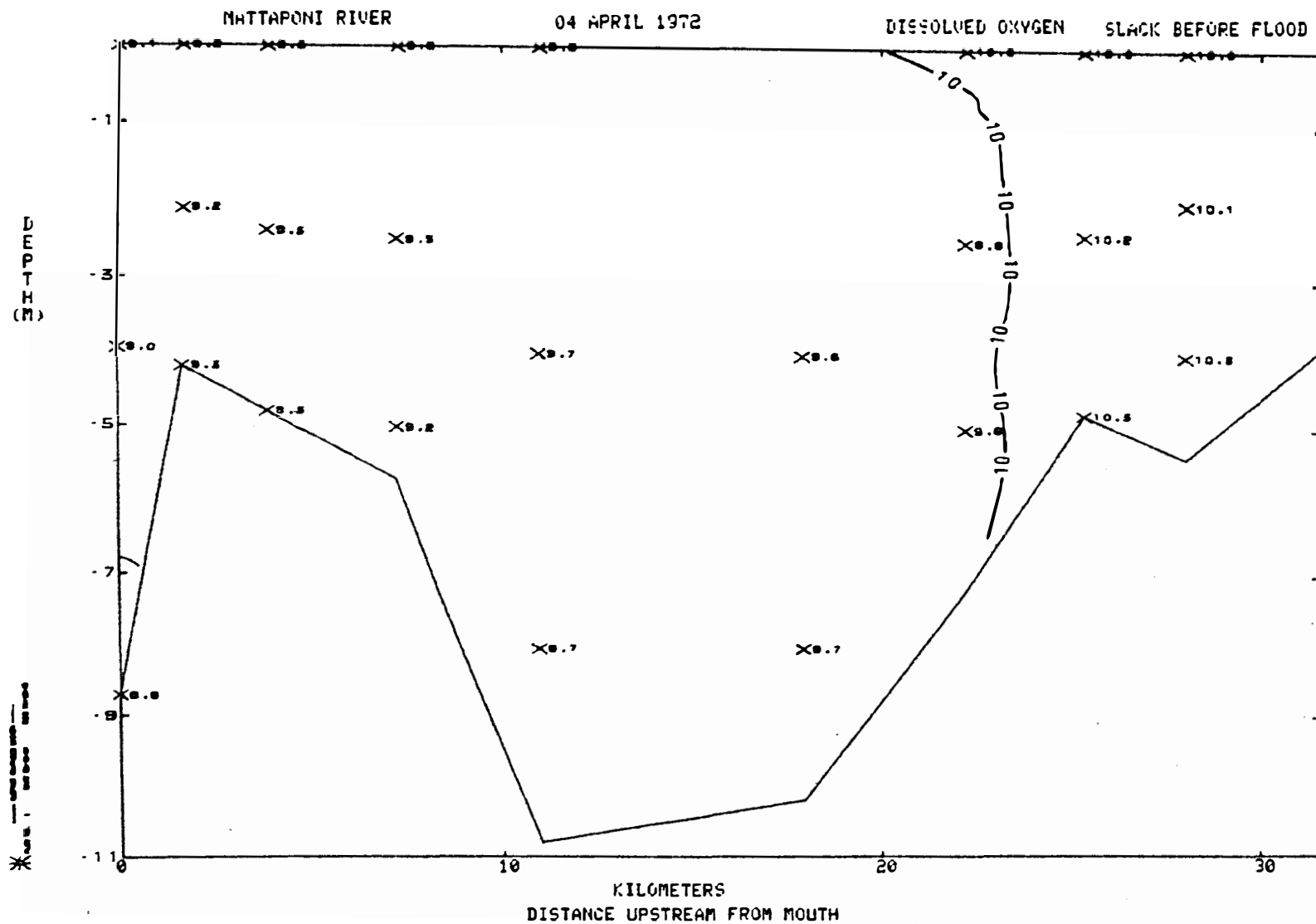


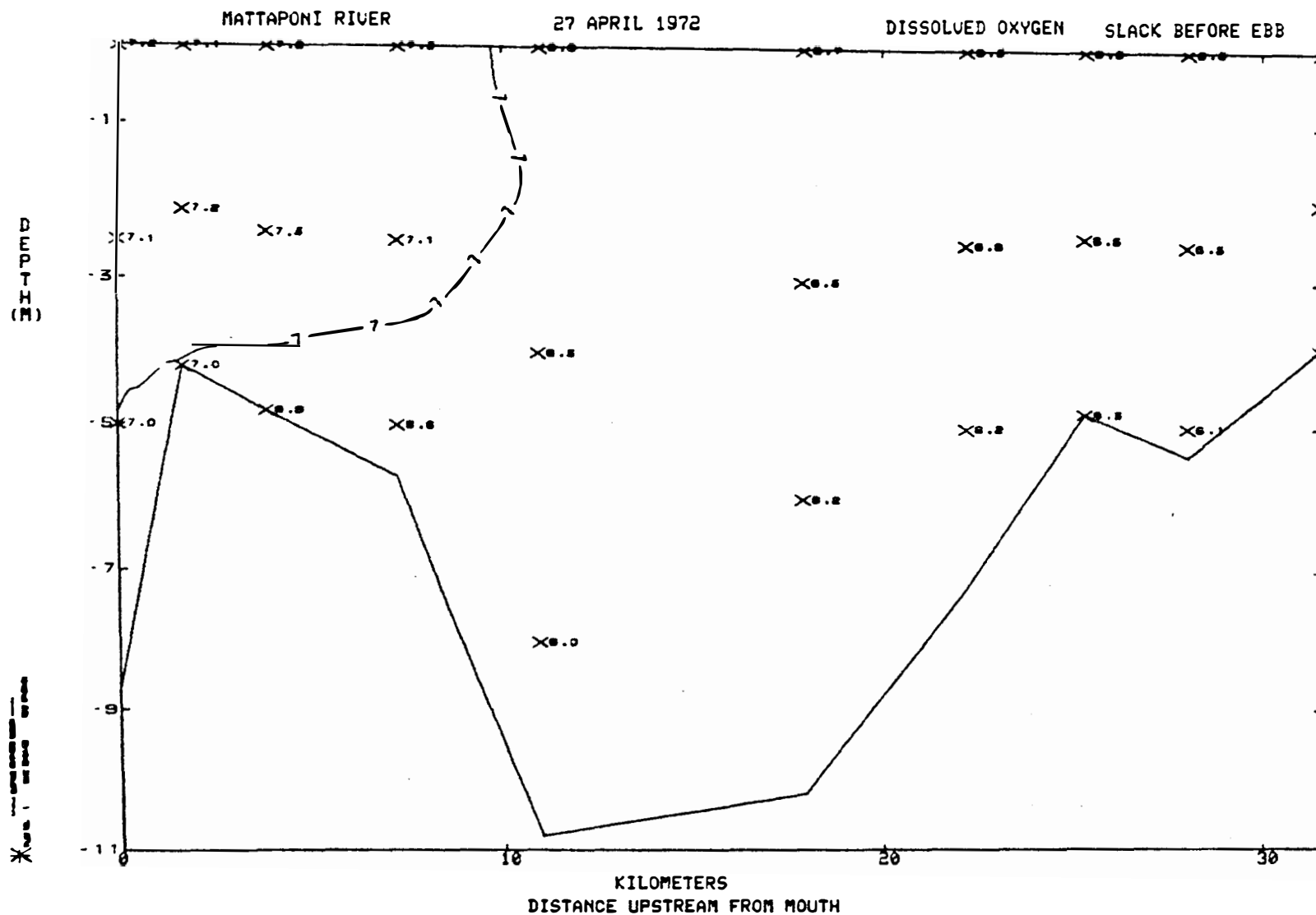


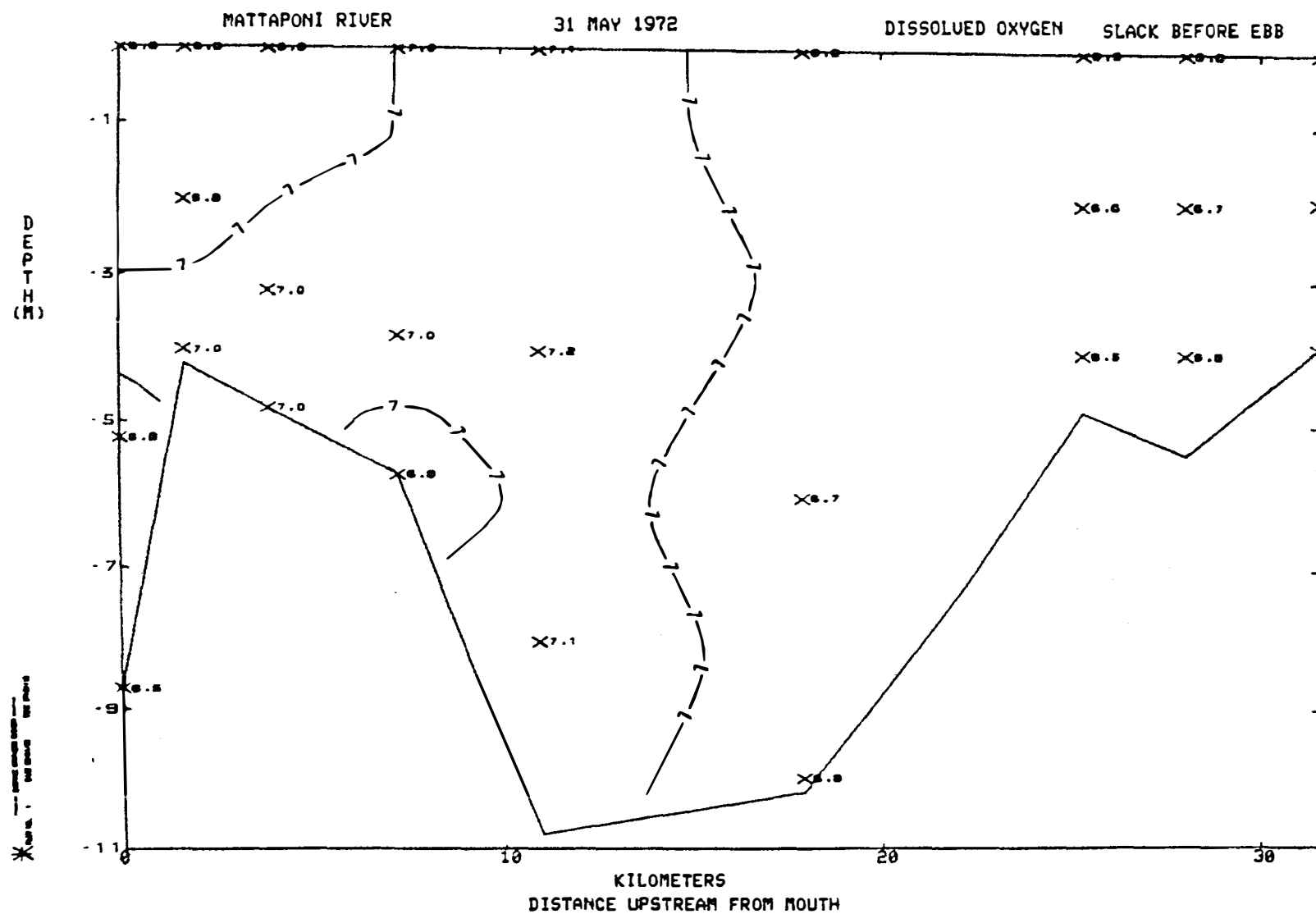


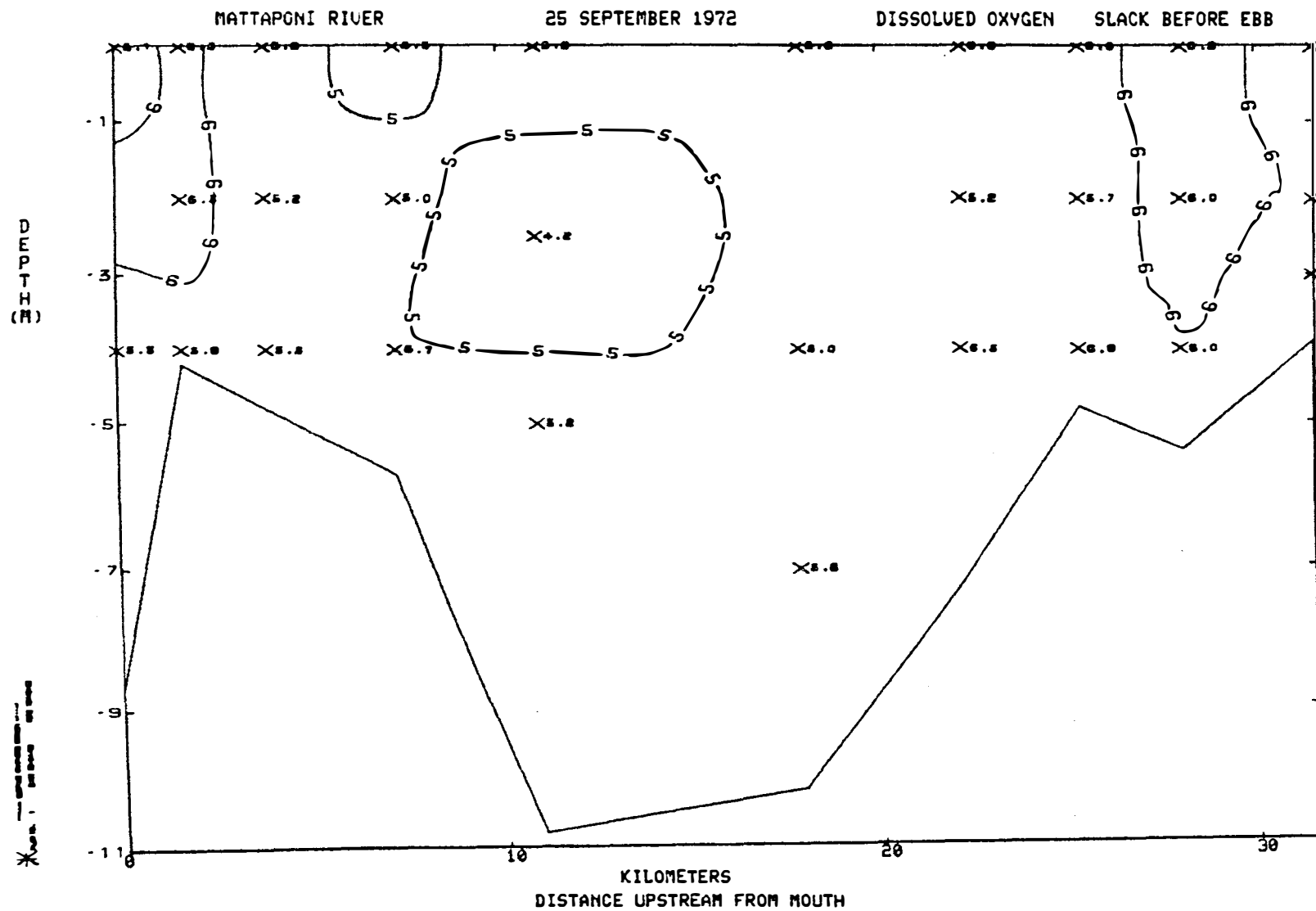


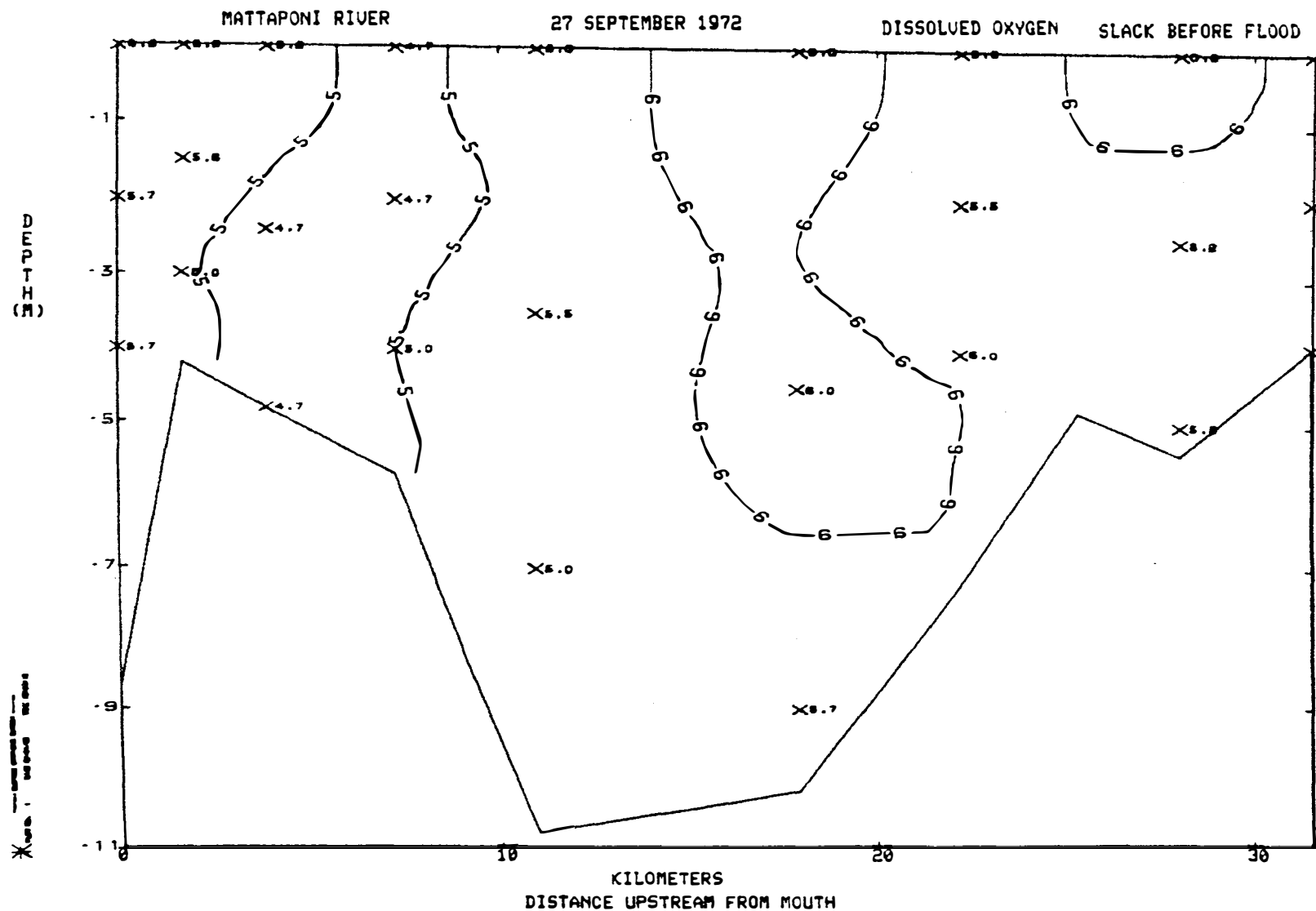




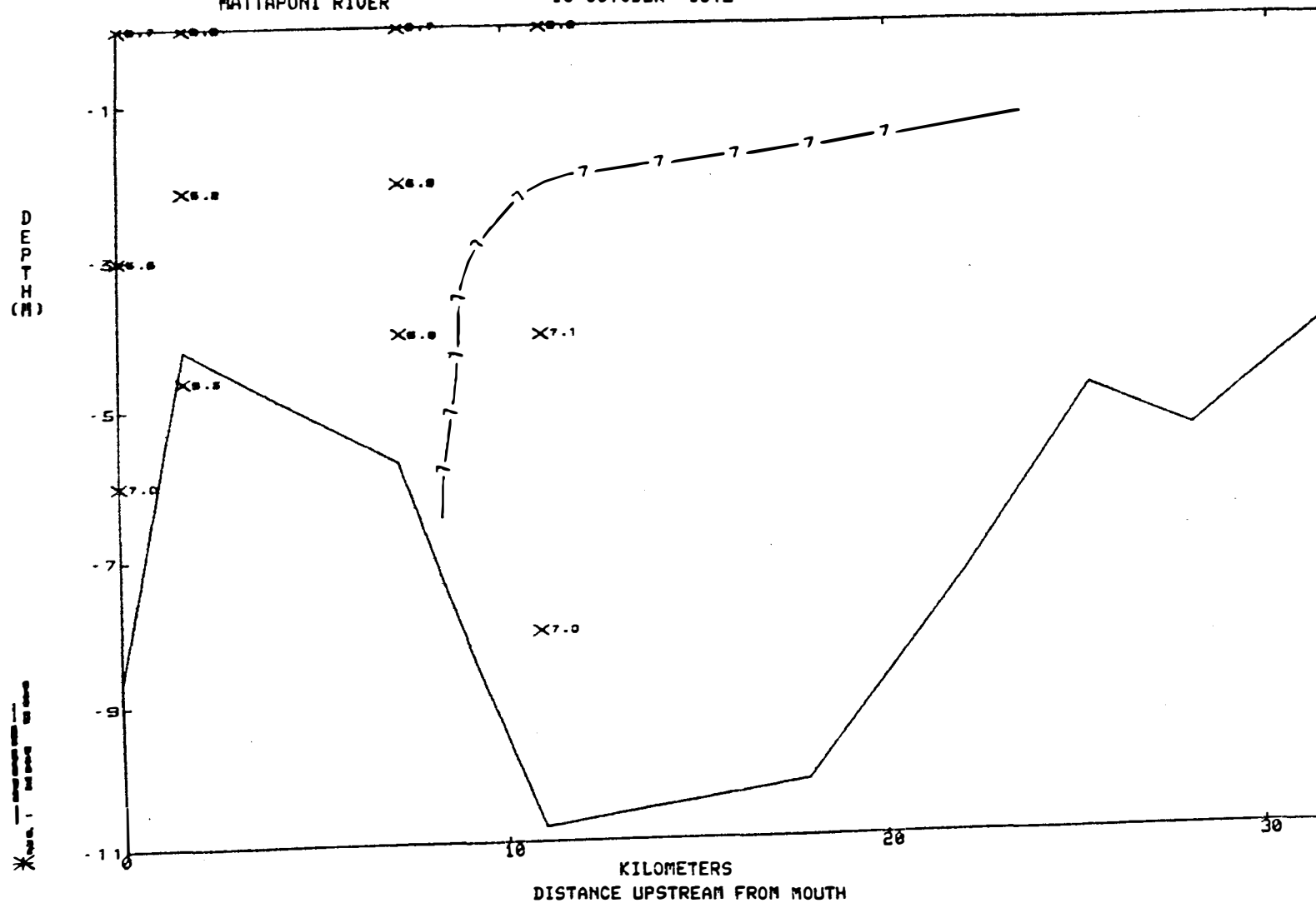


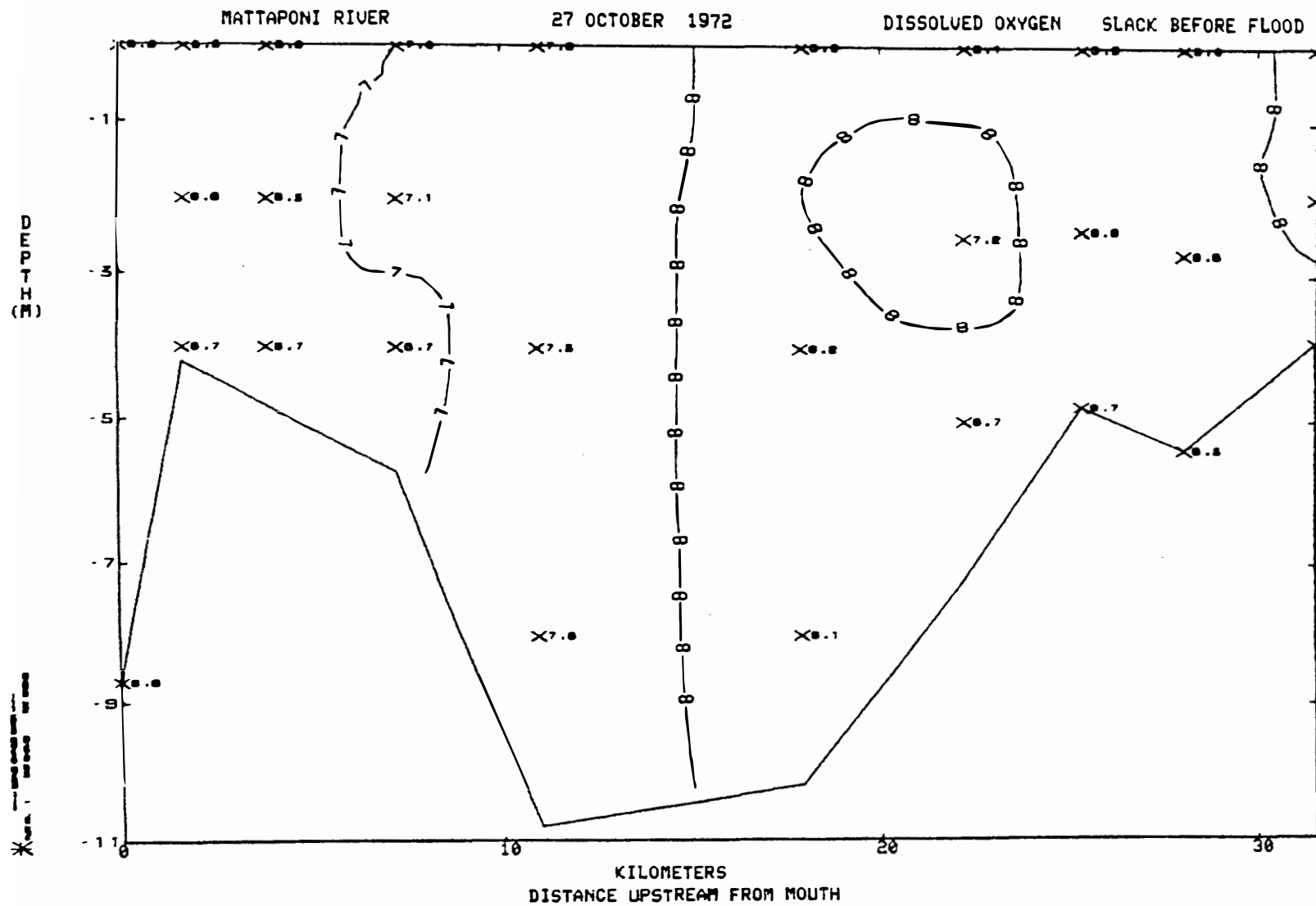


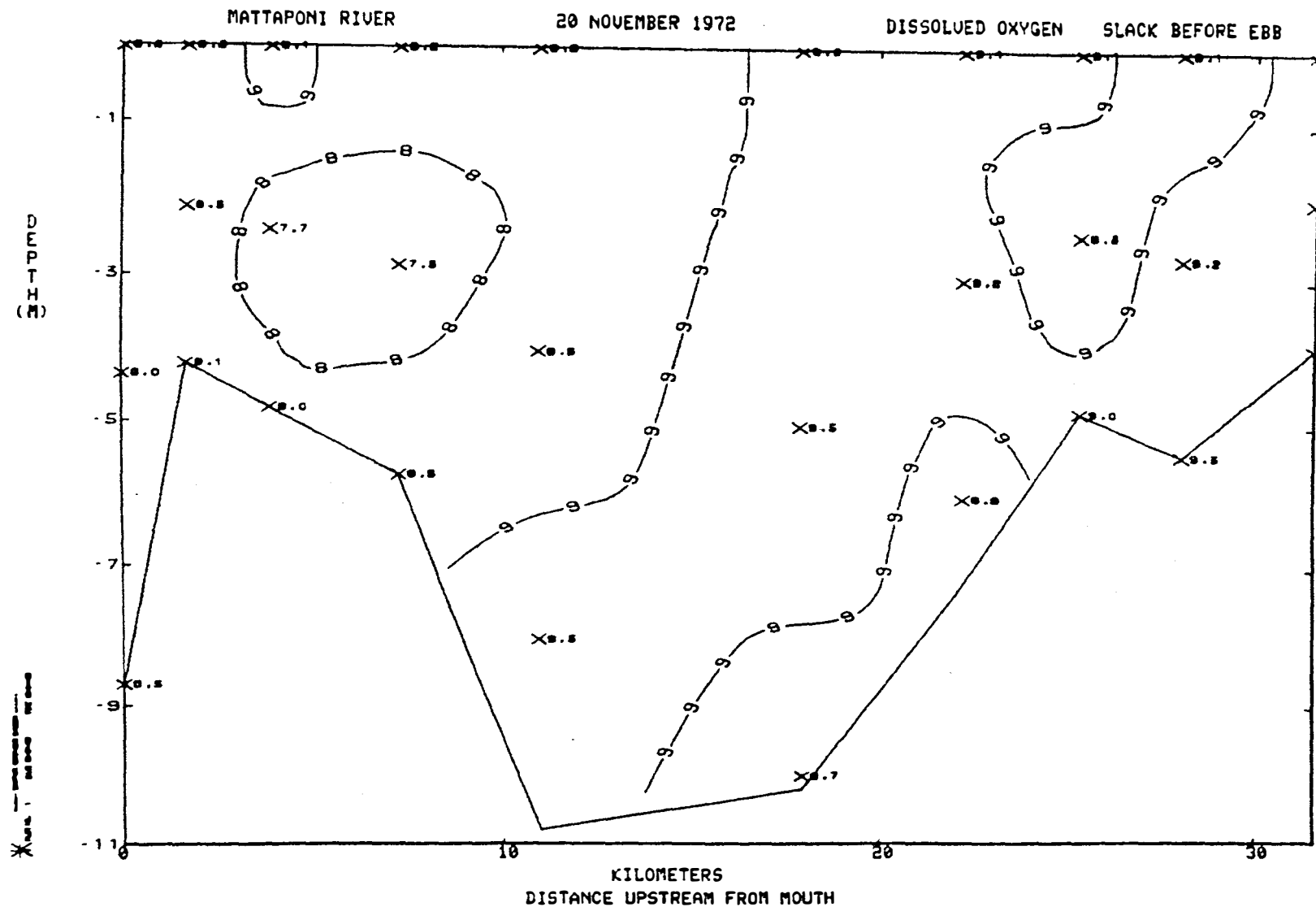


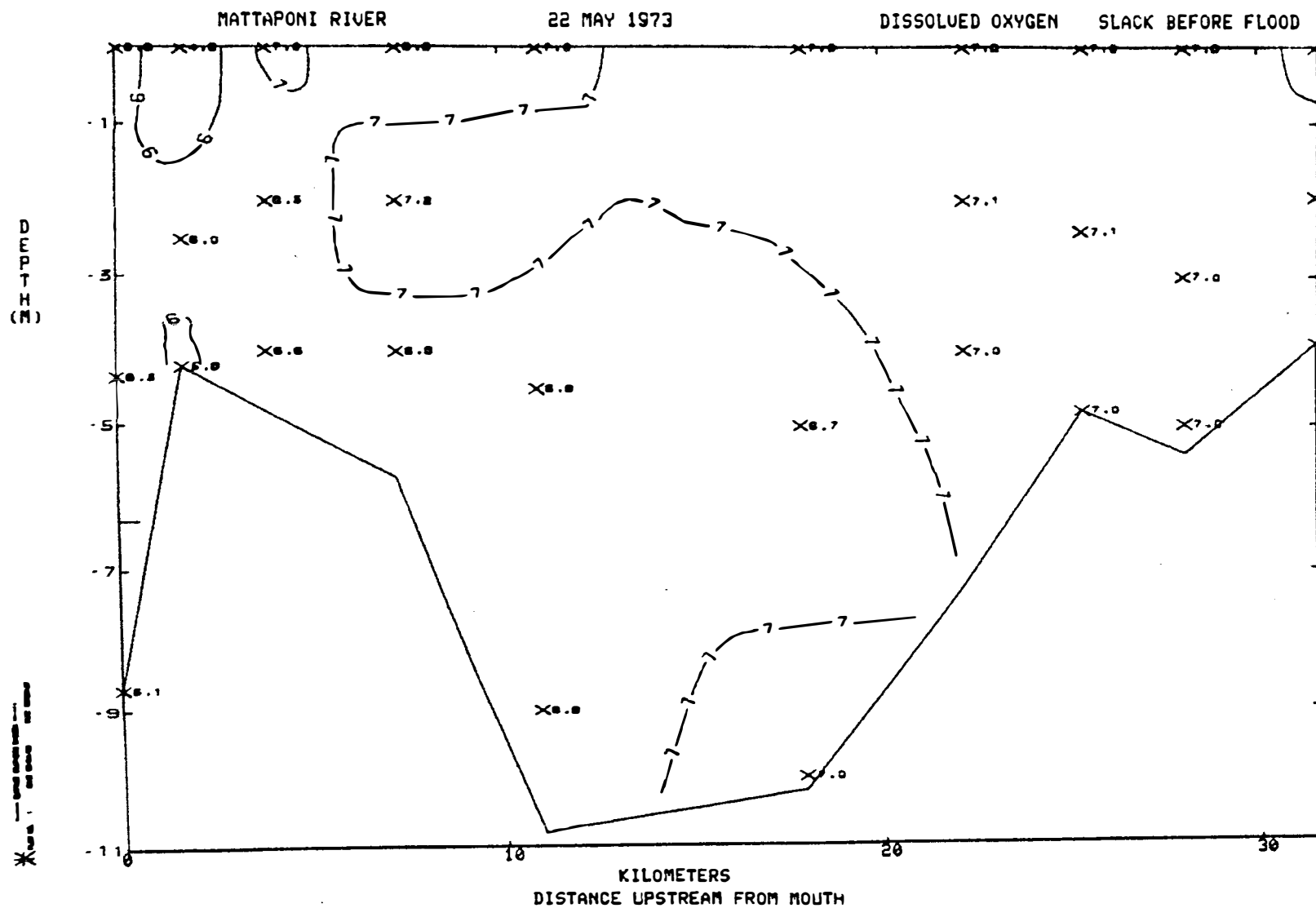


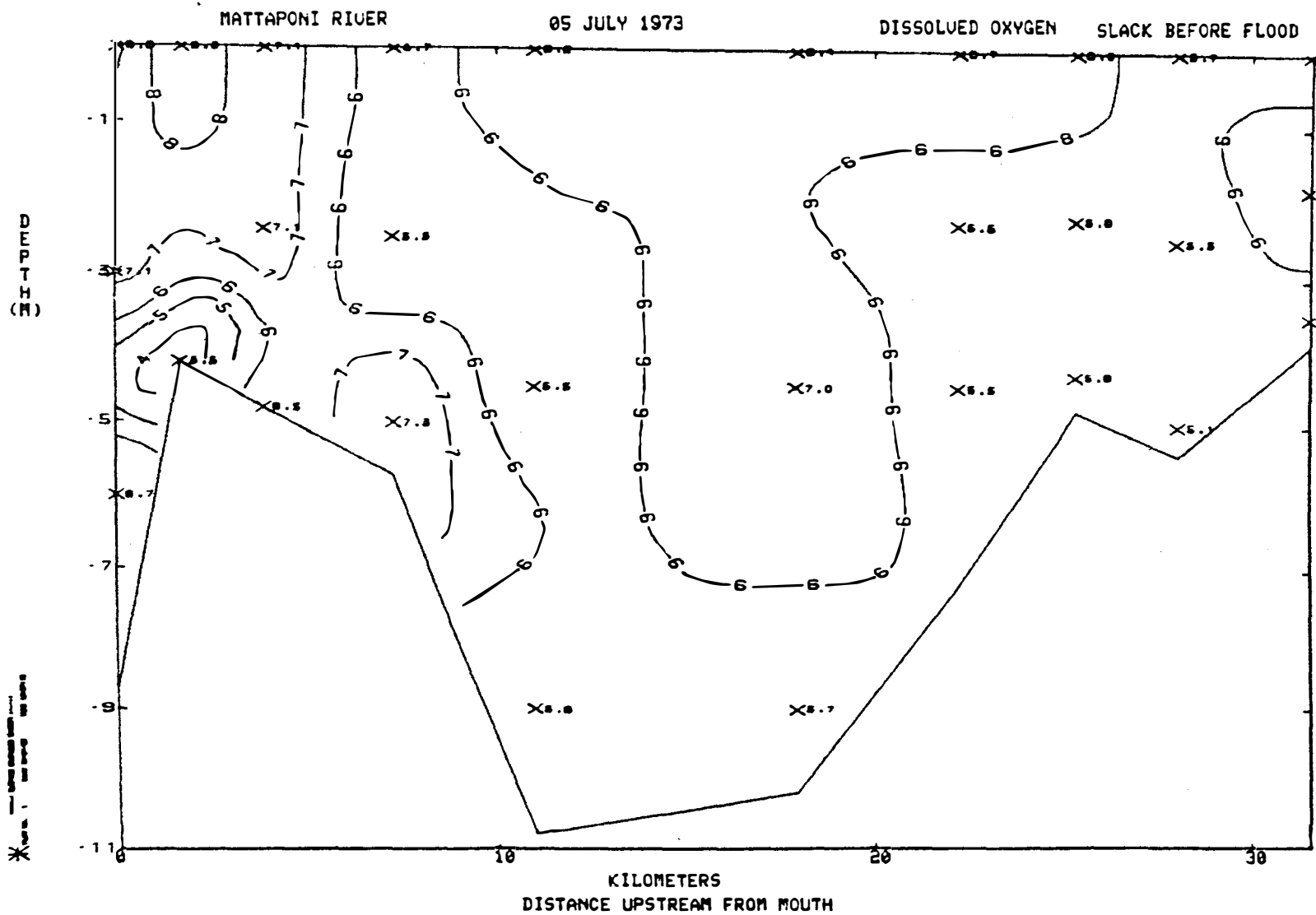
DISSOLVED OXYGEN SLACK BEFORE EBB

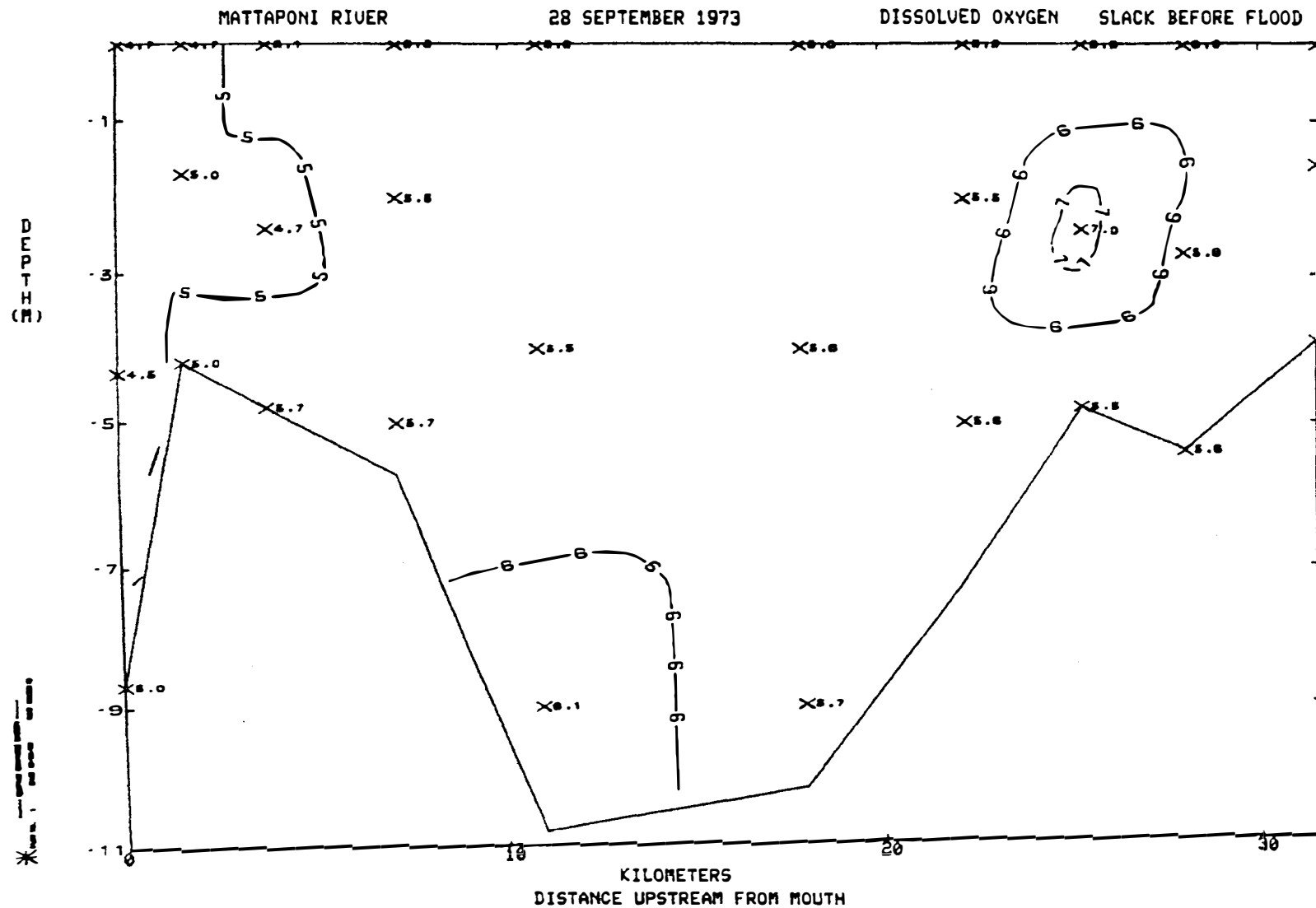










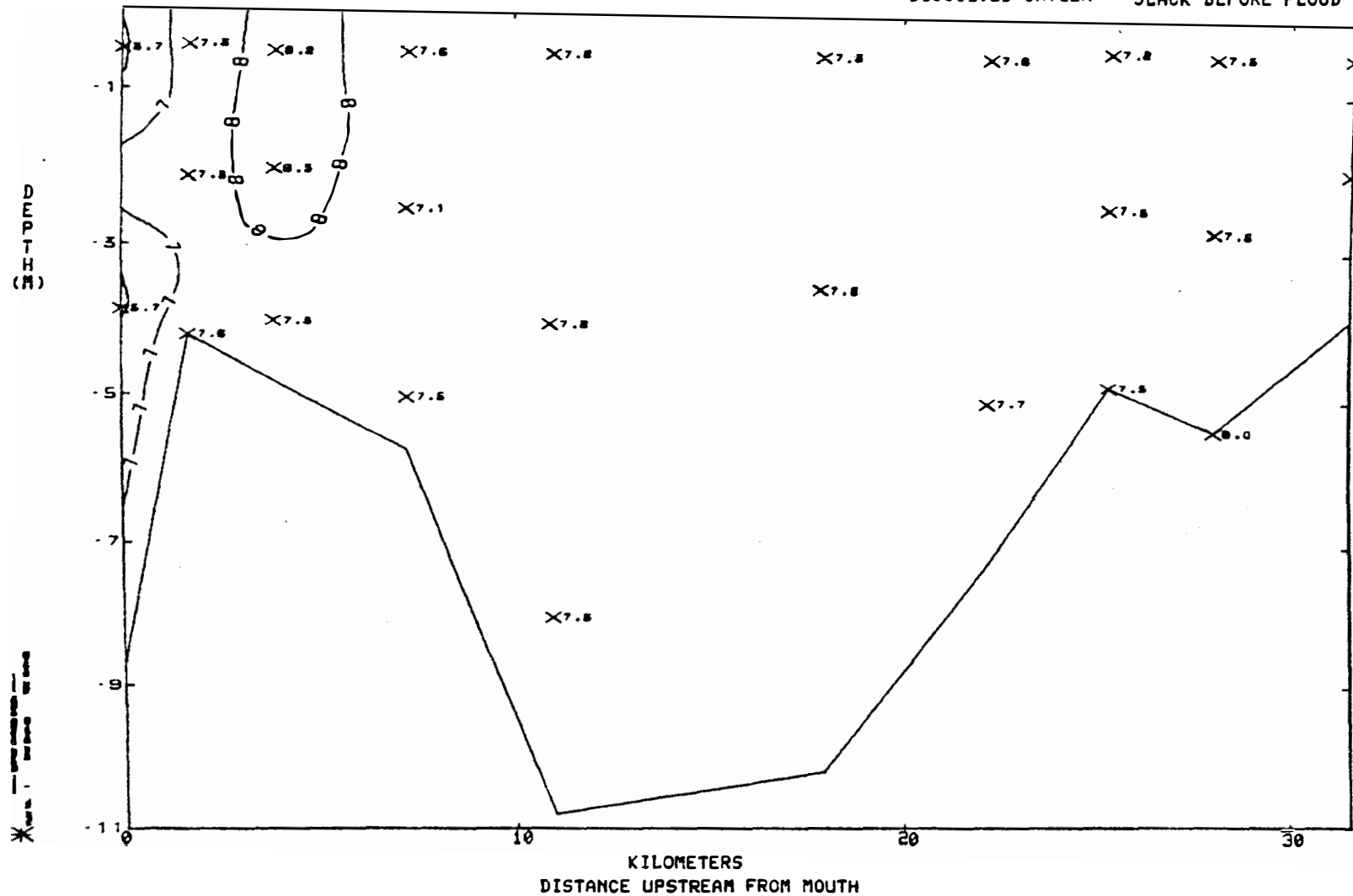


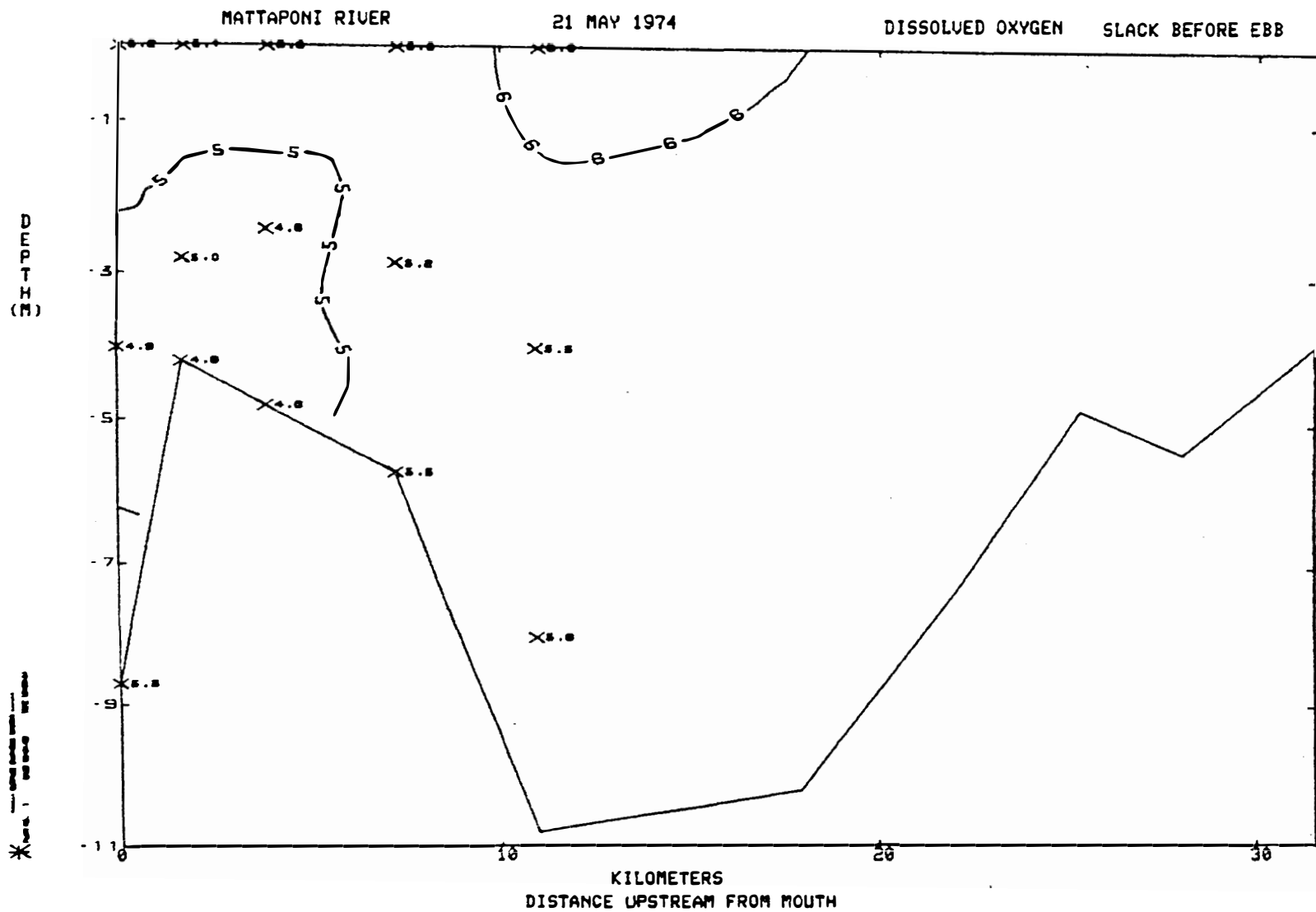
MATTAPONI RIVER

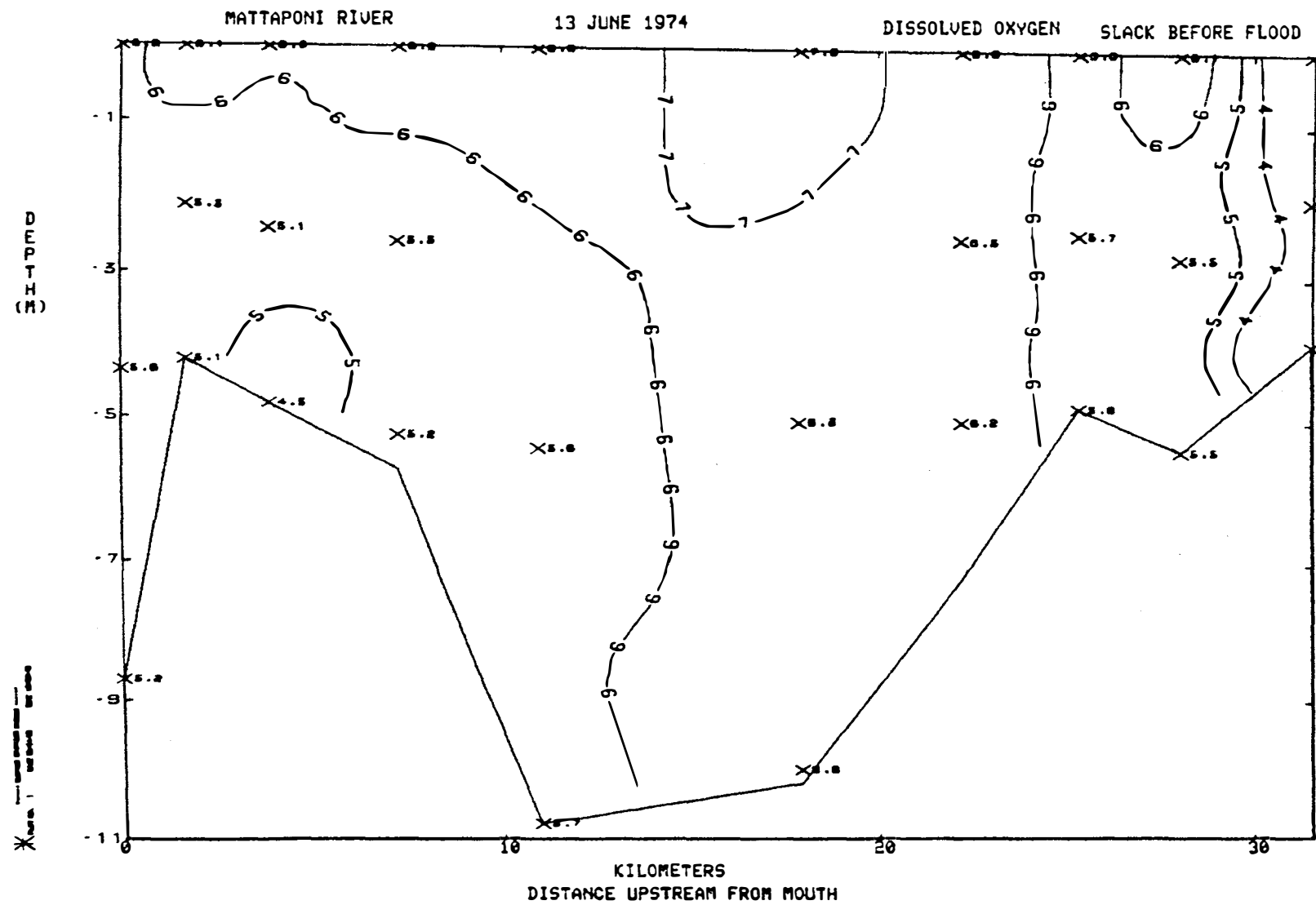
31 OCTOBER 1973

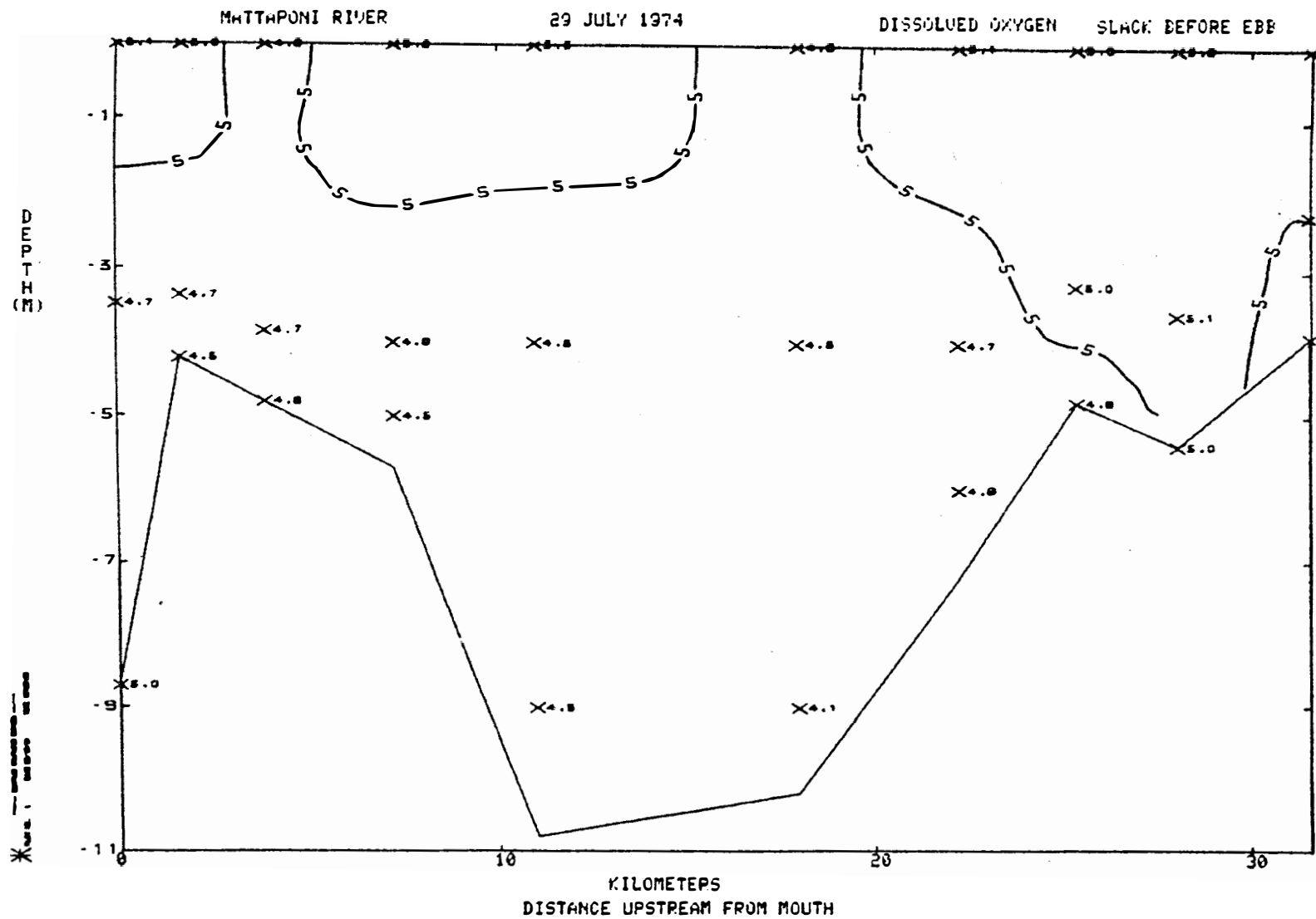
DISSOLVED OXYGEN

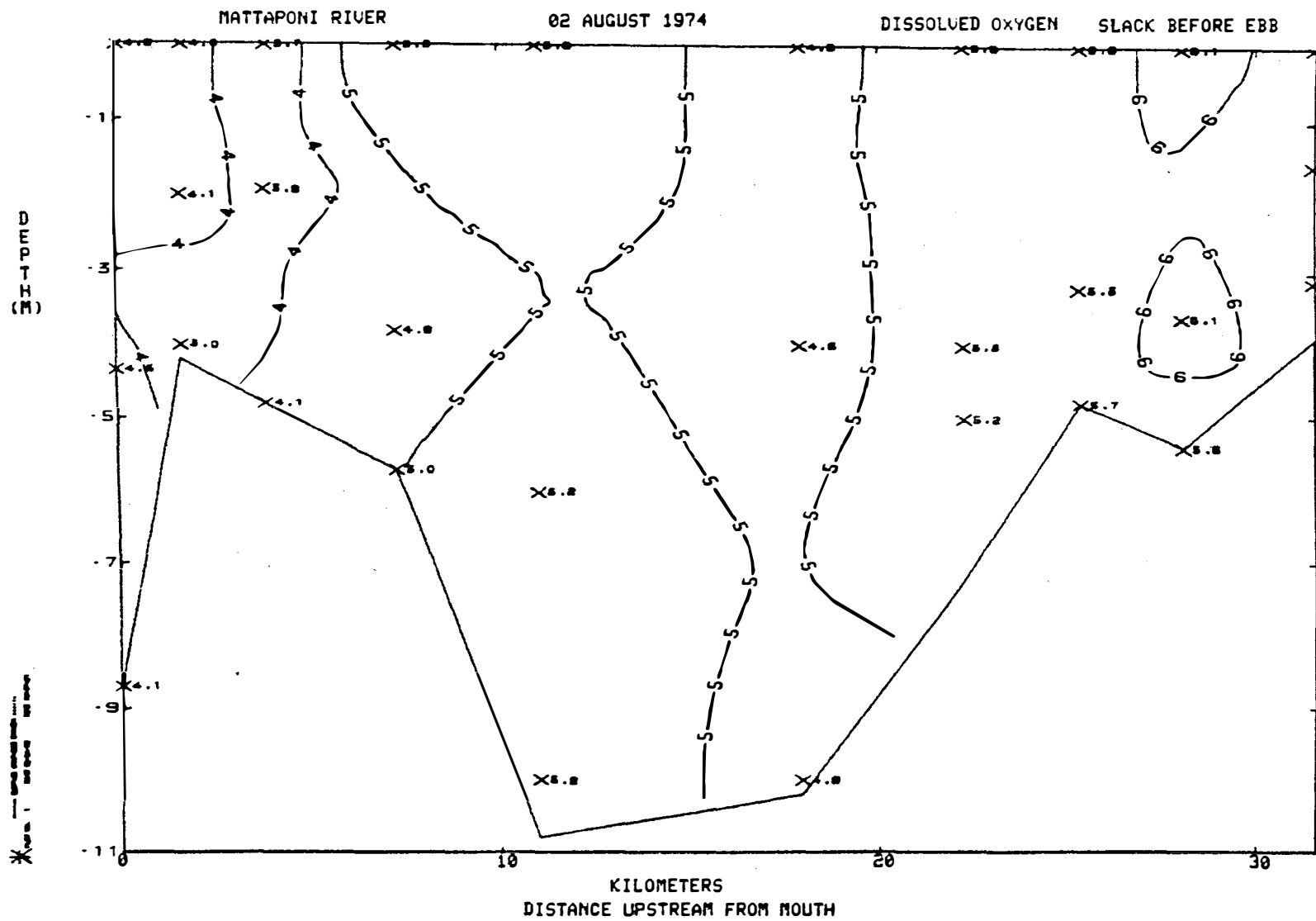
SLACK BEFORE FLOOD

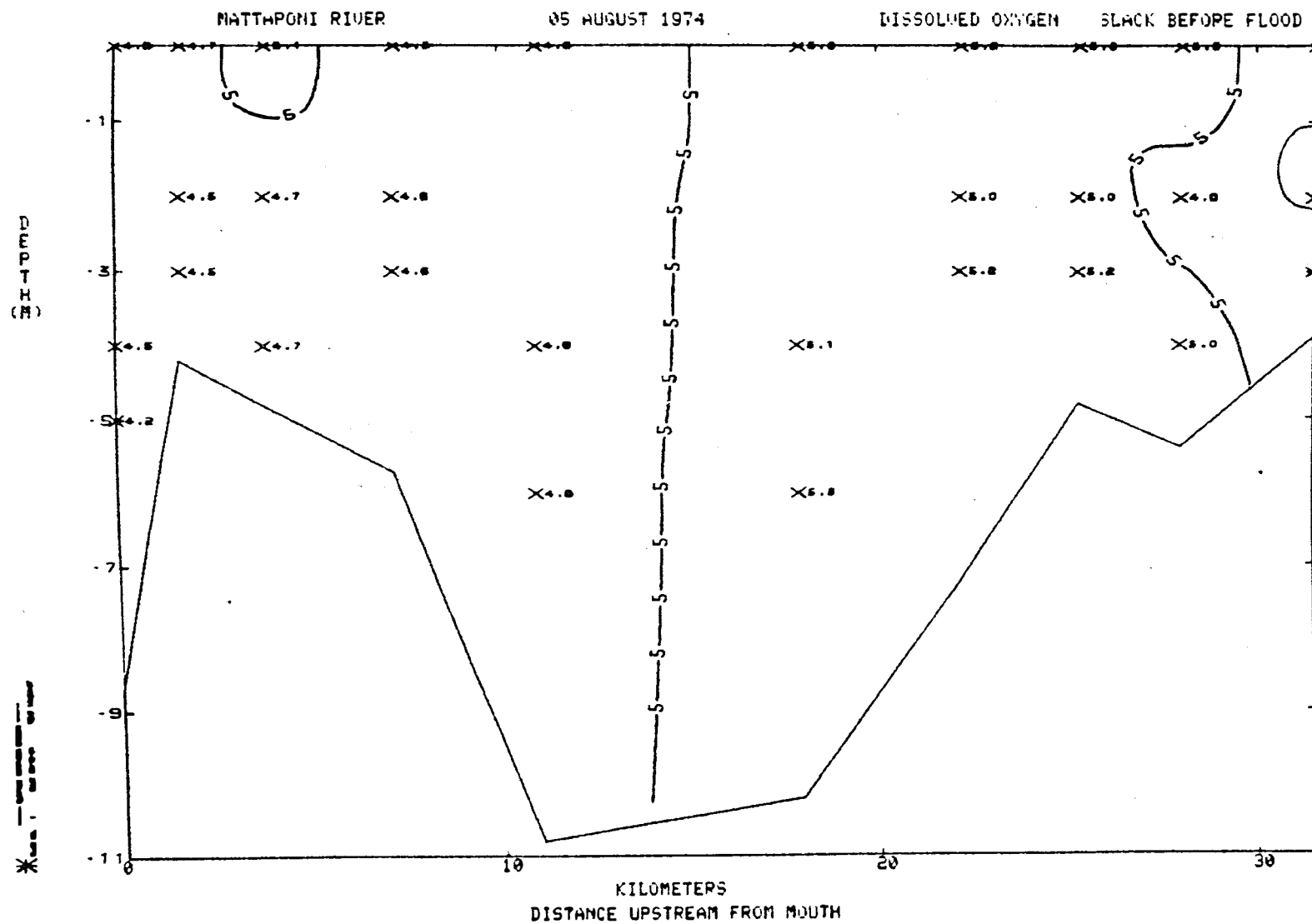


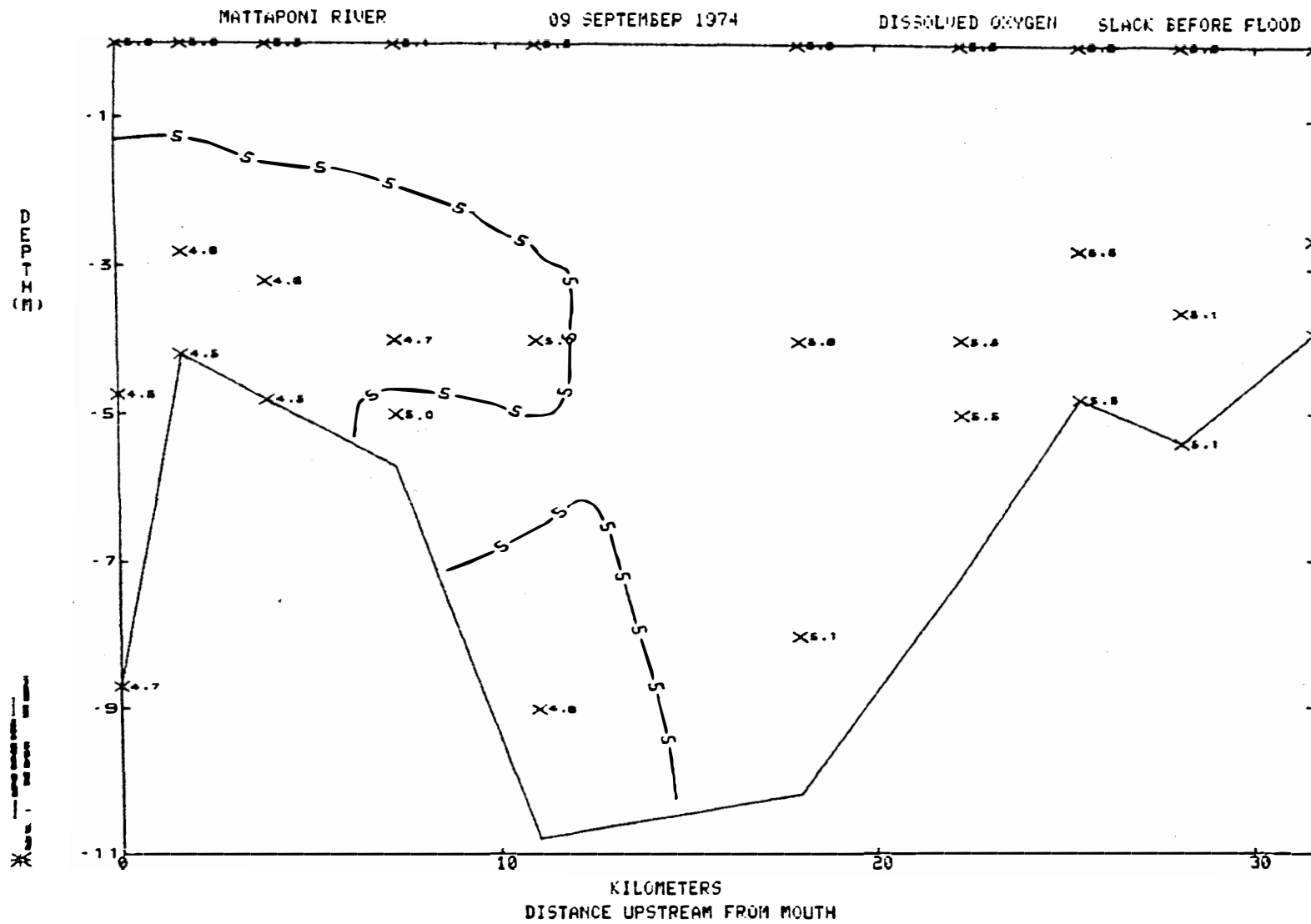


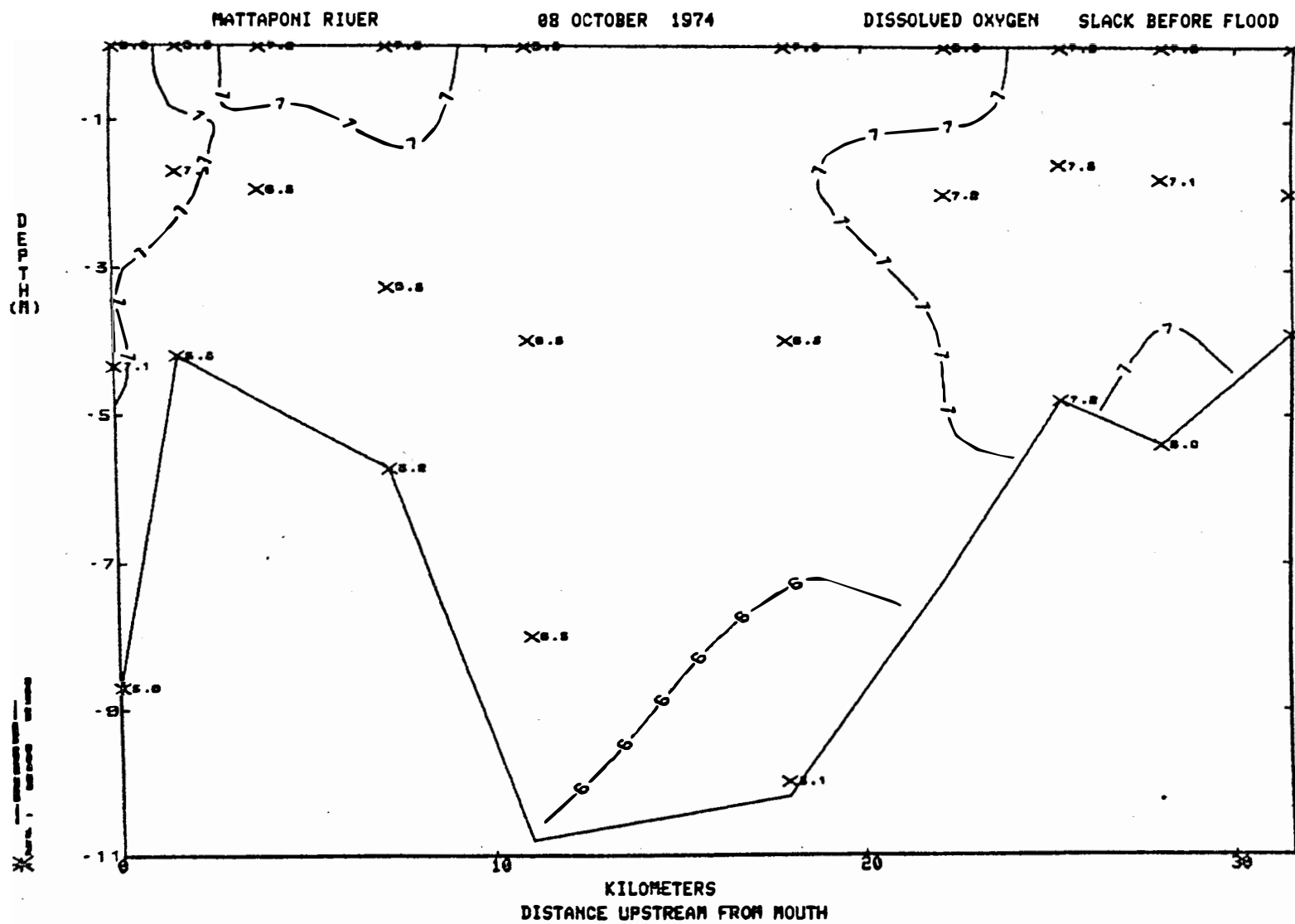


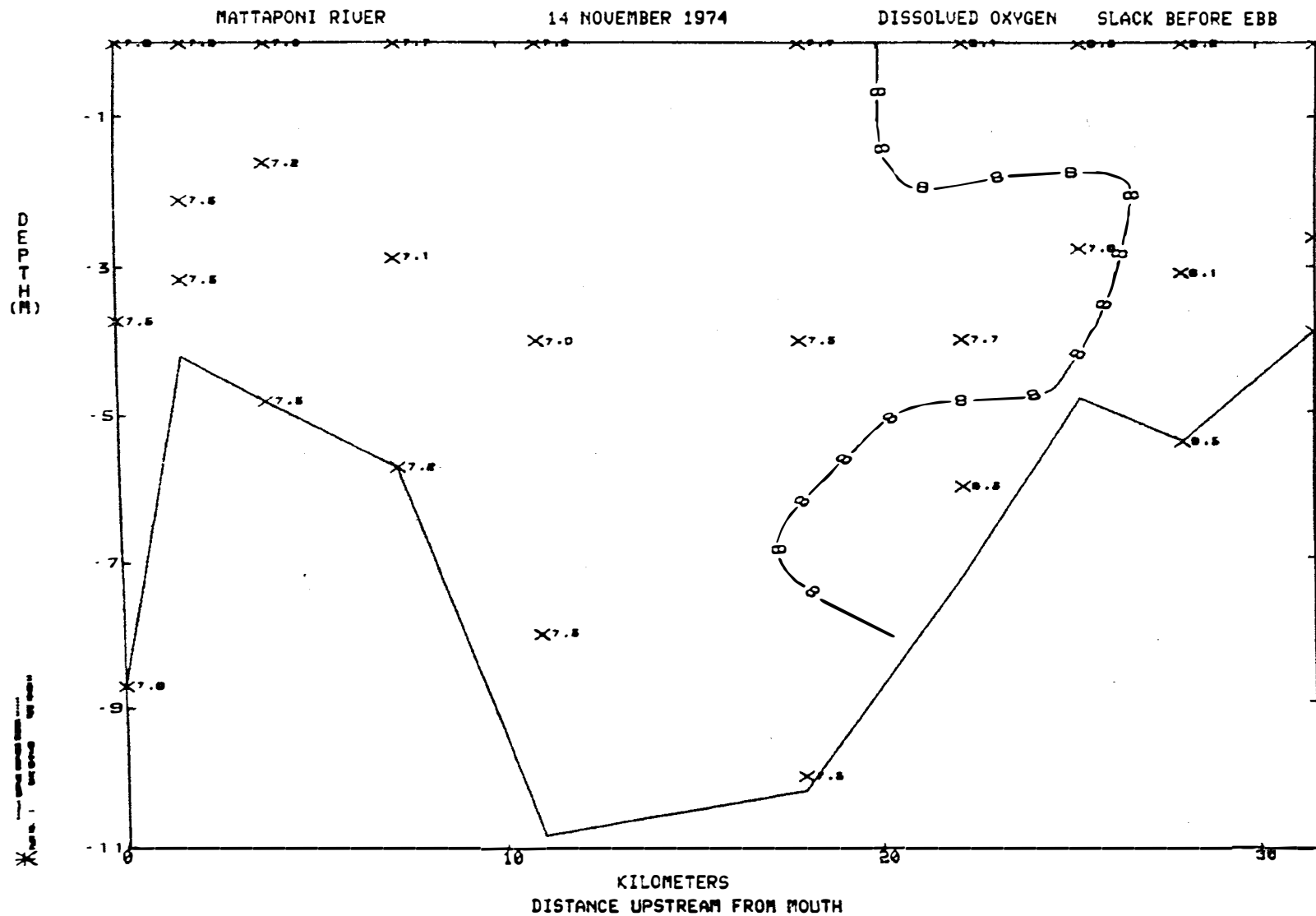


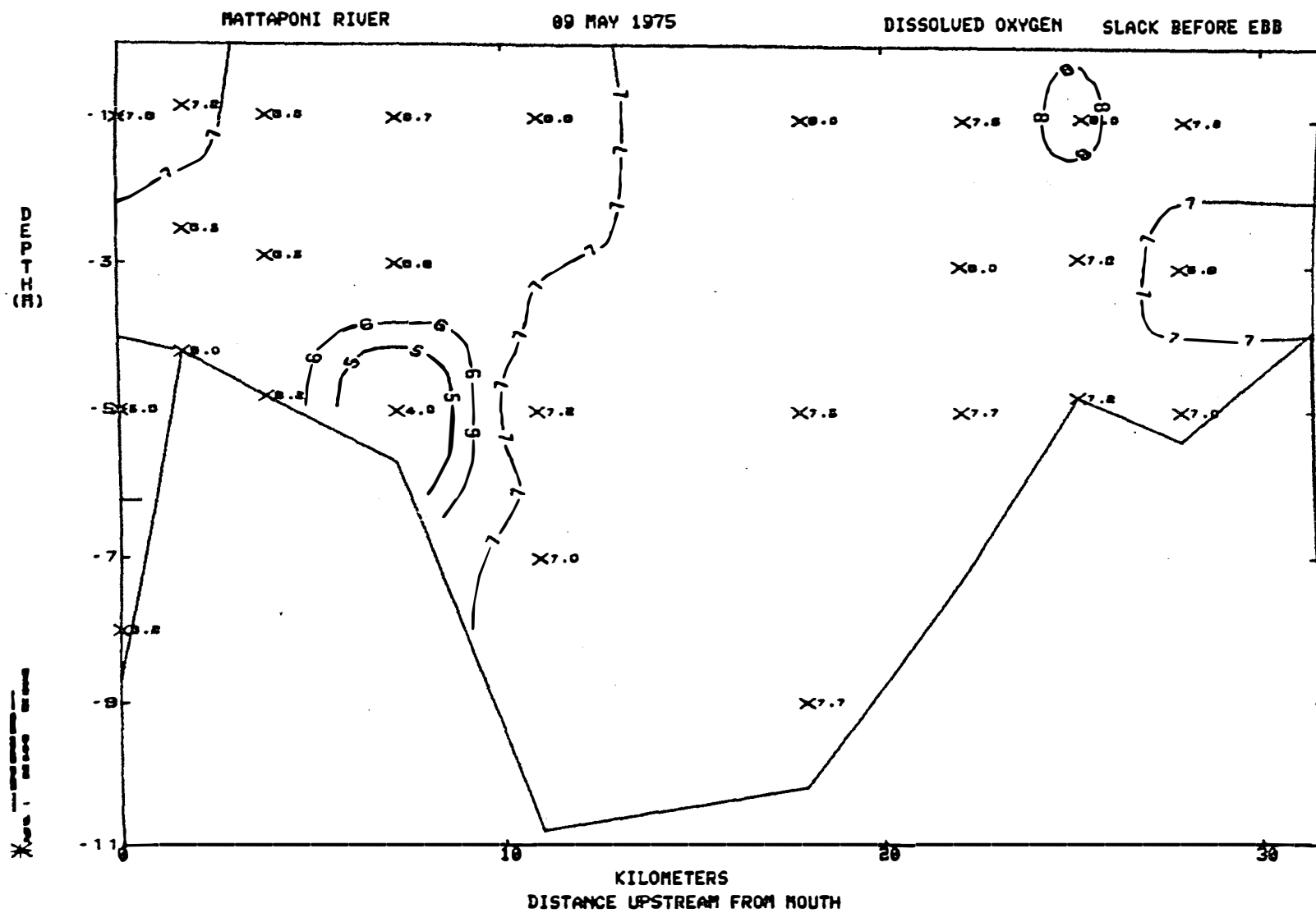










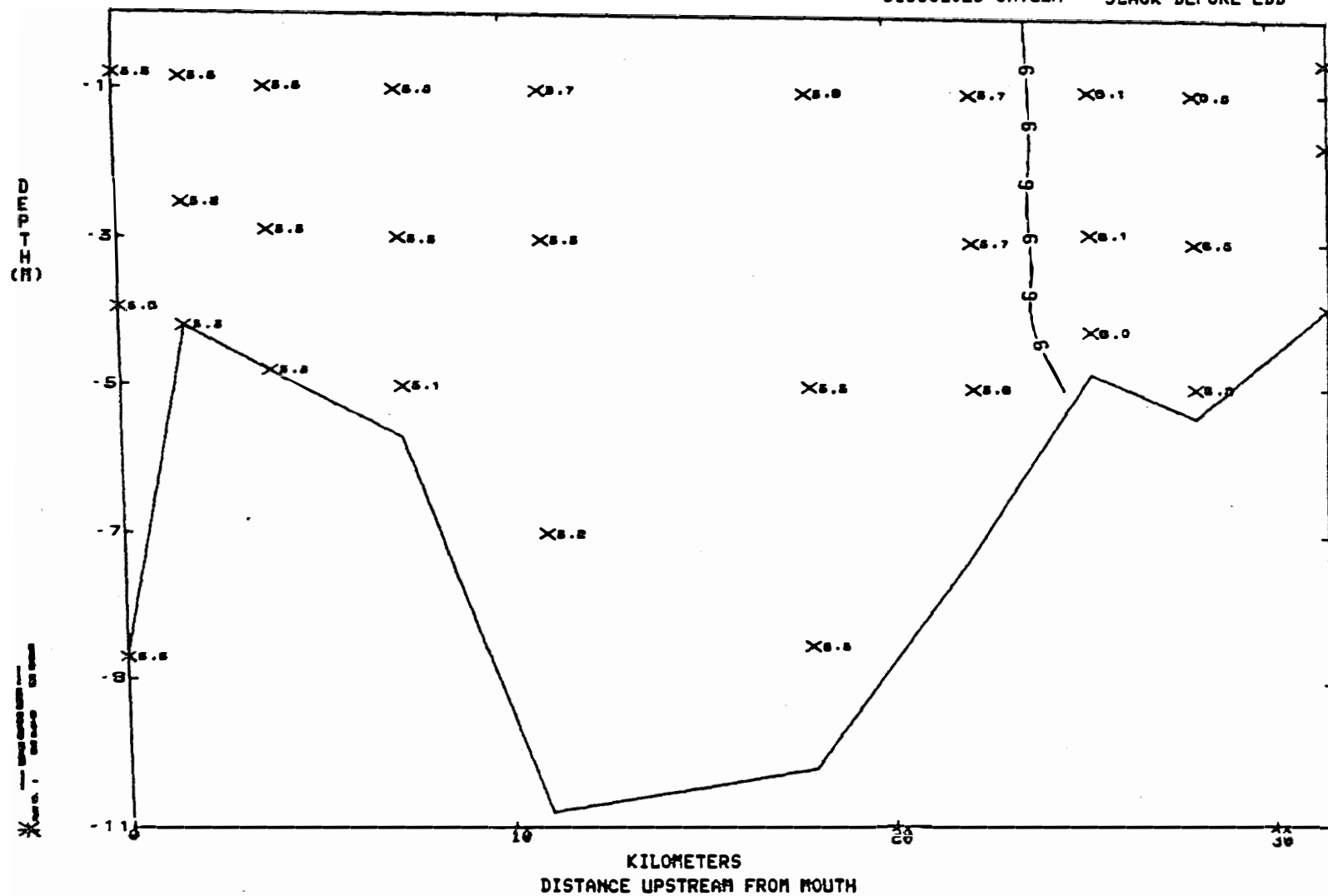


MATTAPONI RIVER

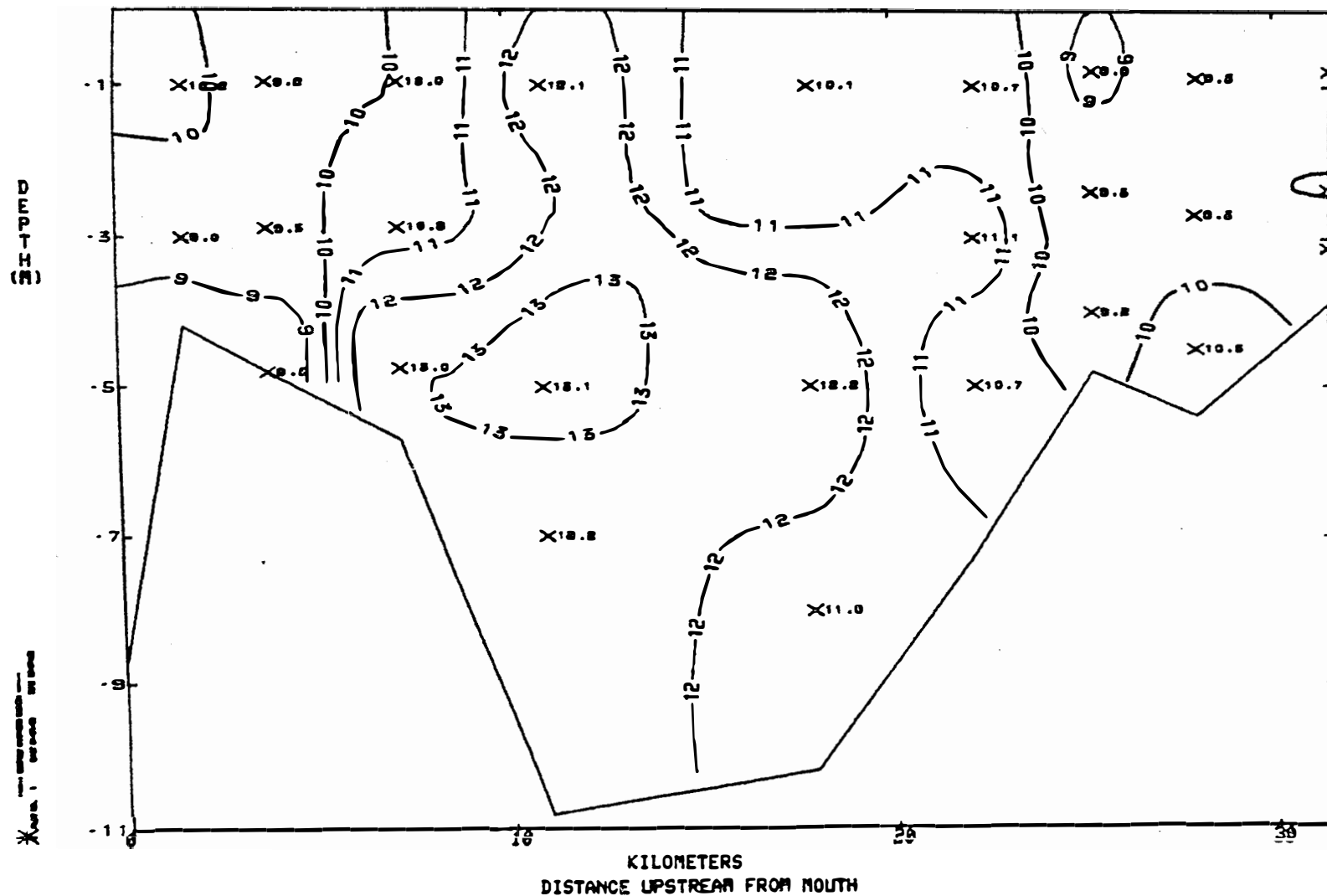
17 OCTOBER 1975

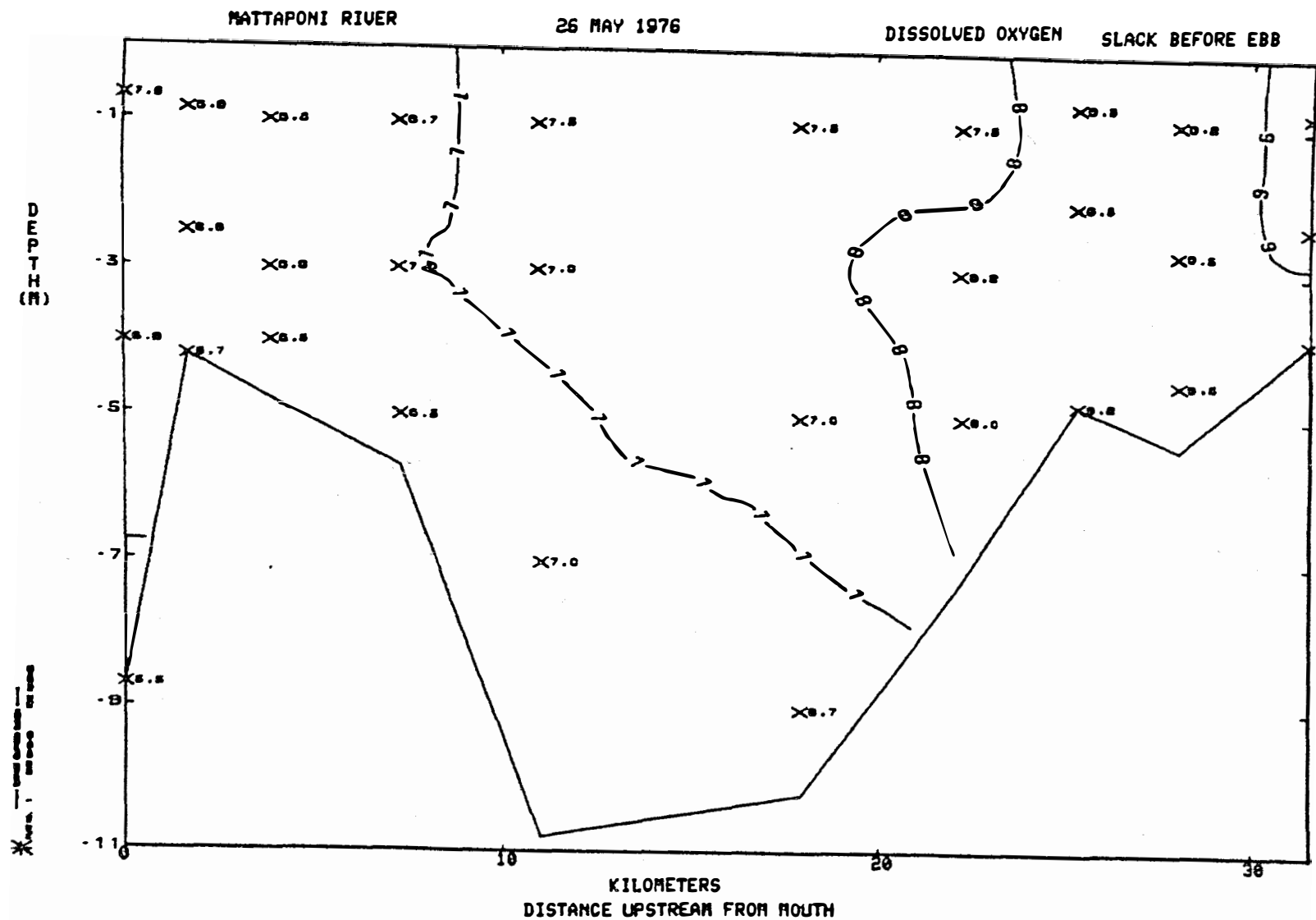
DISSOLVED OXYGEN

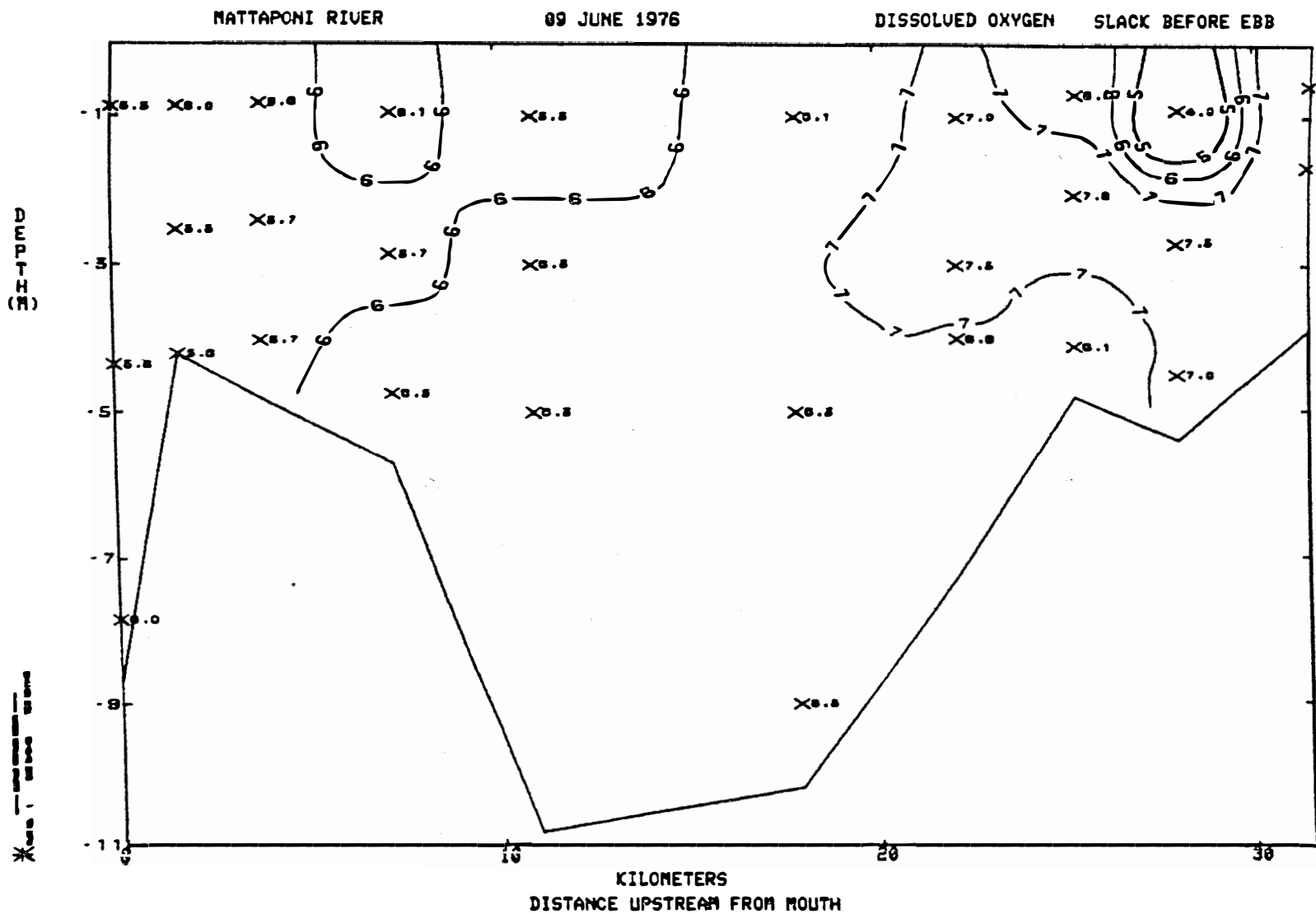
SLACK BEFORE EBB

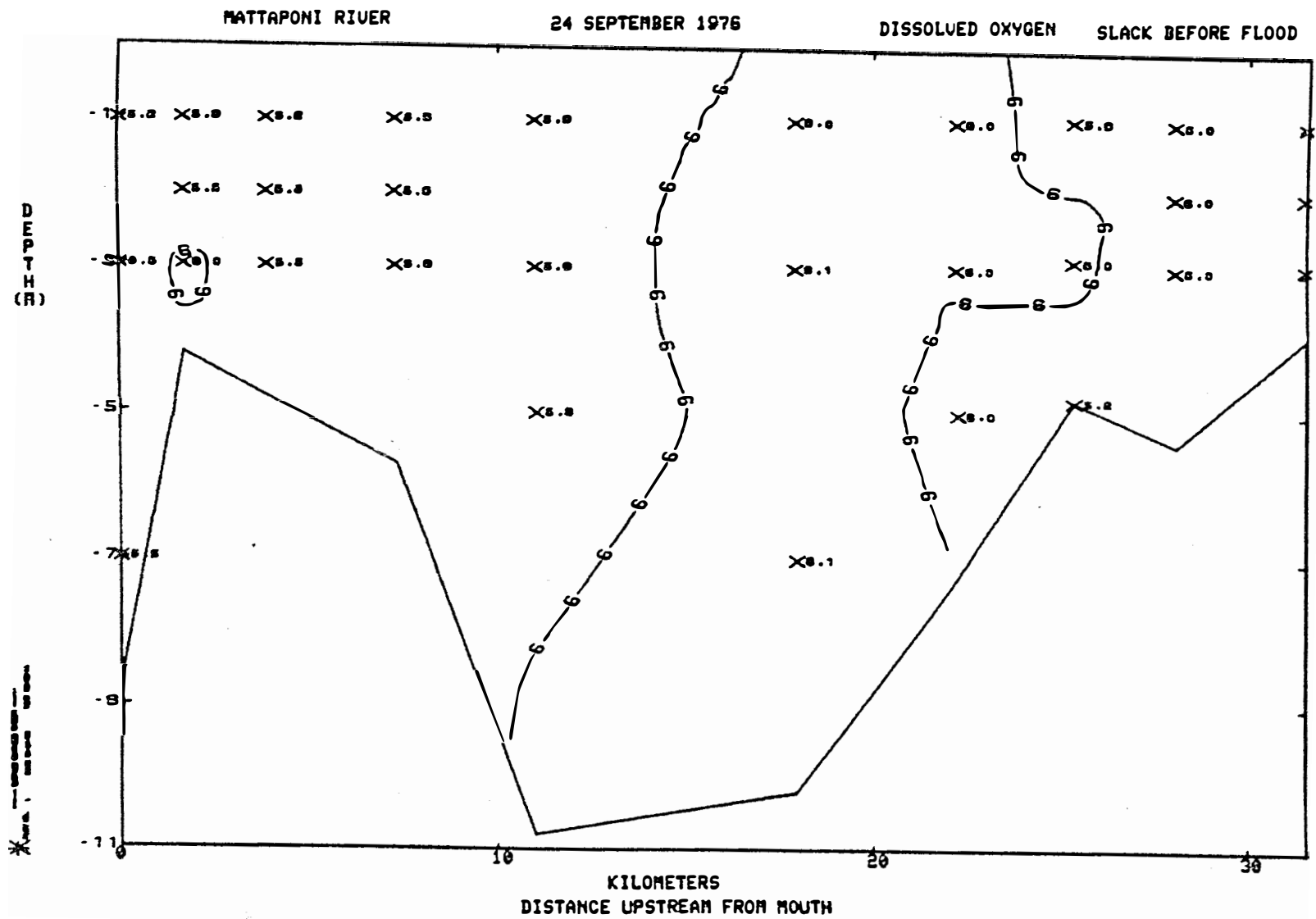


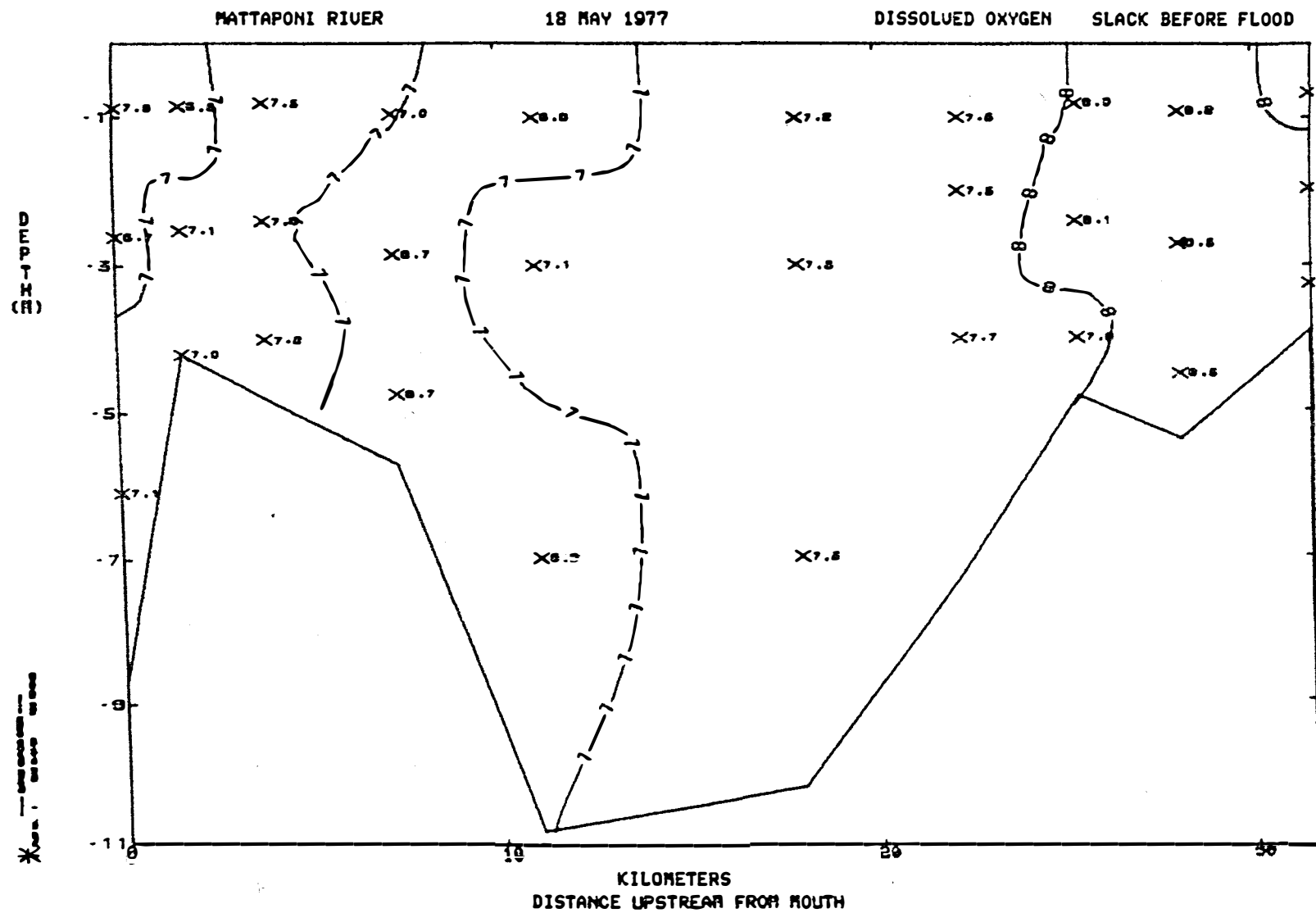
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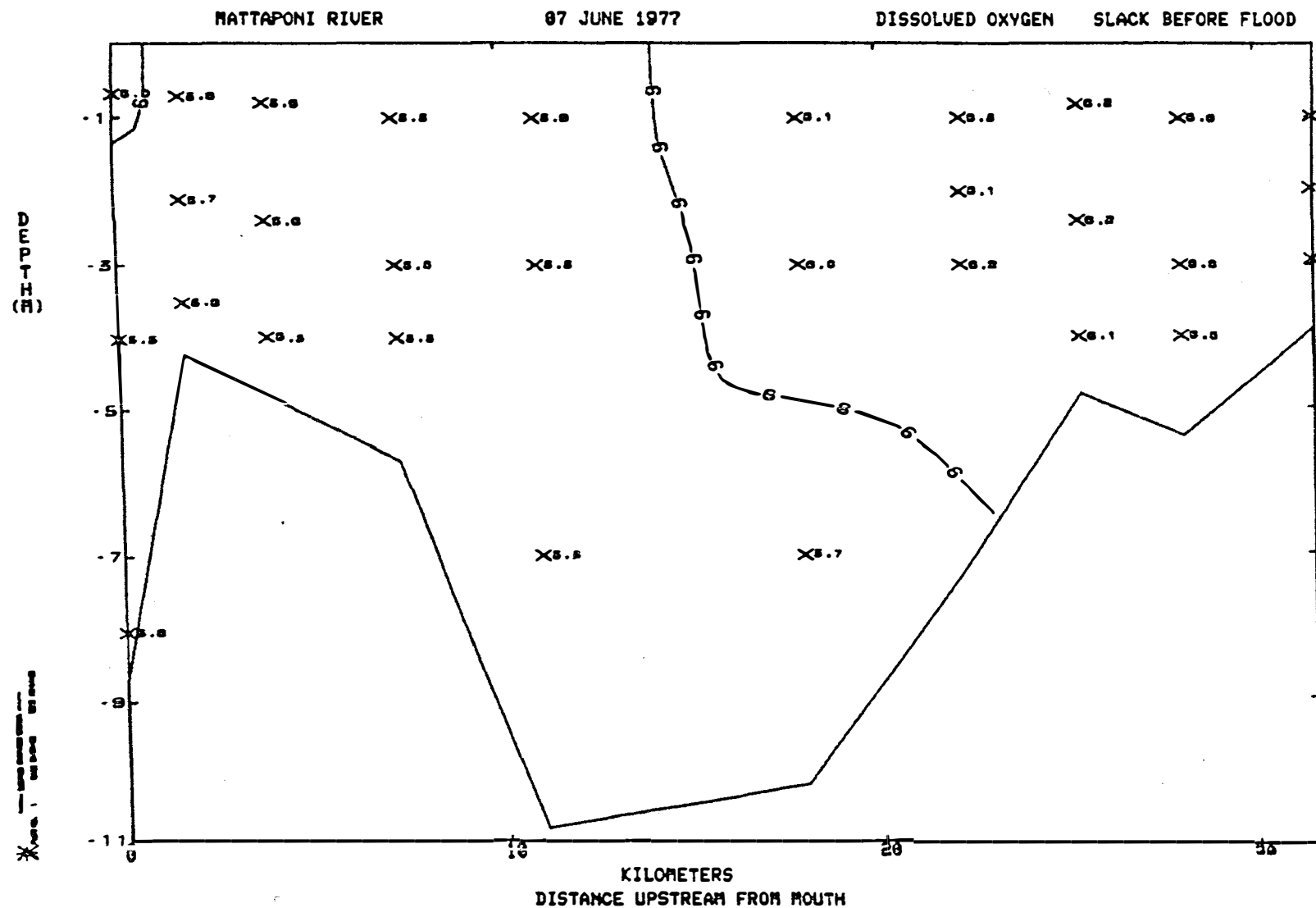


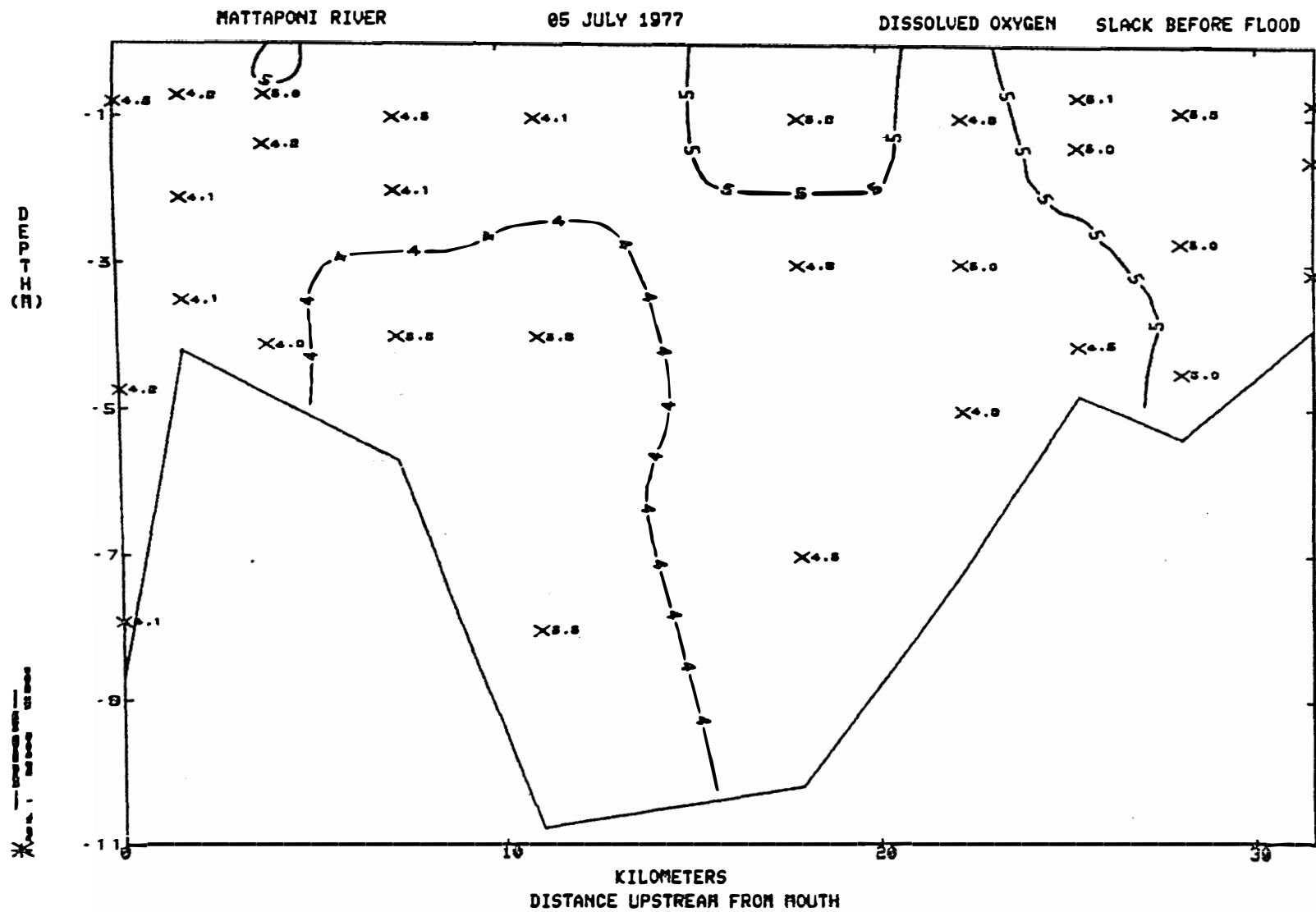


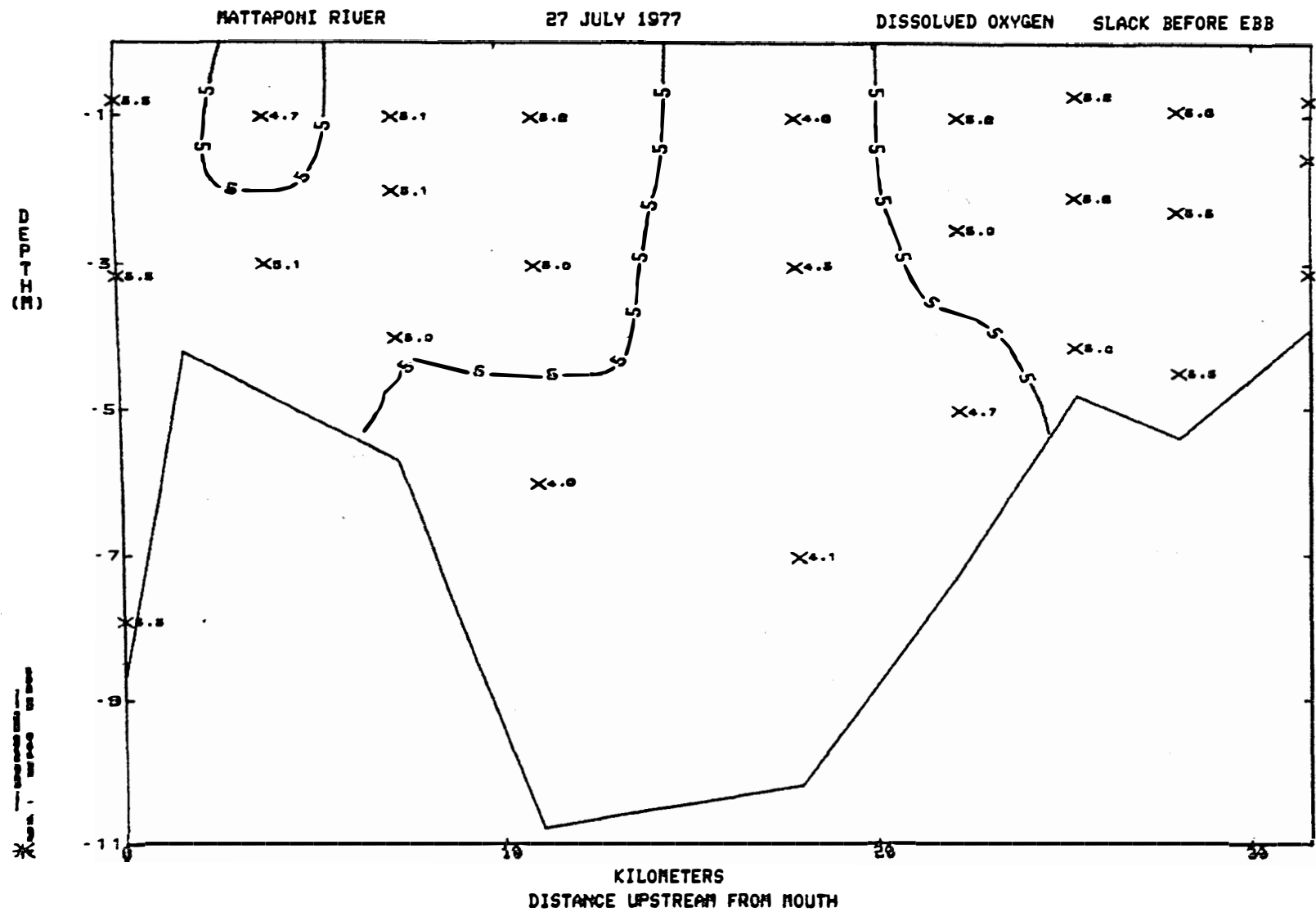




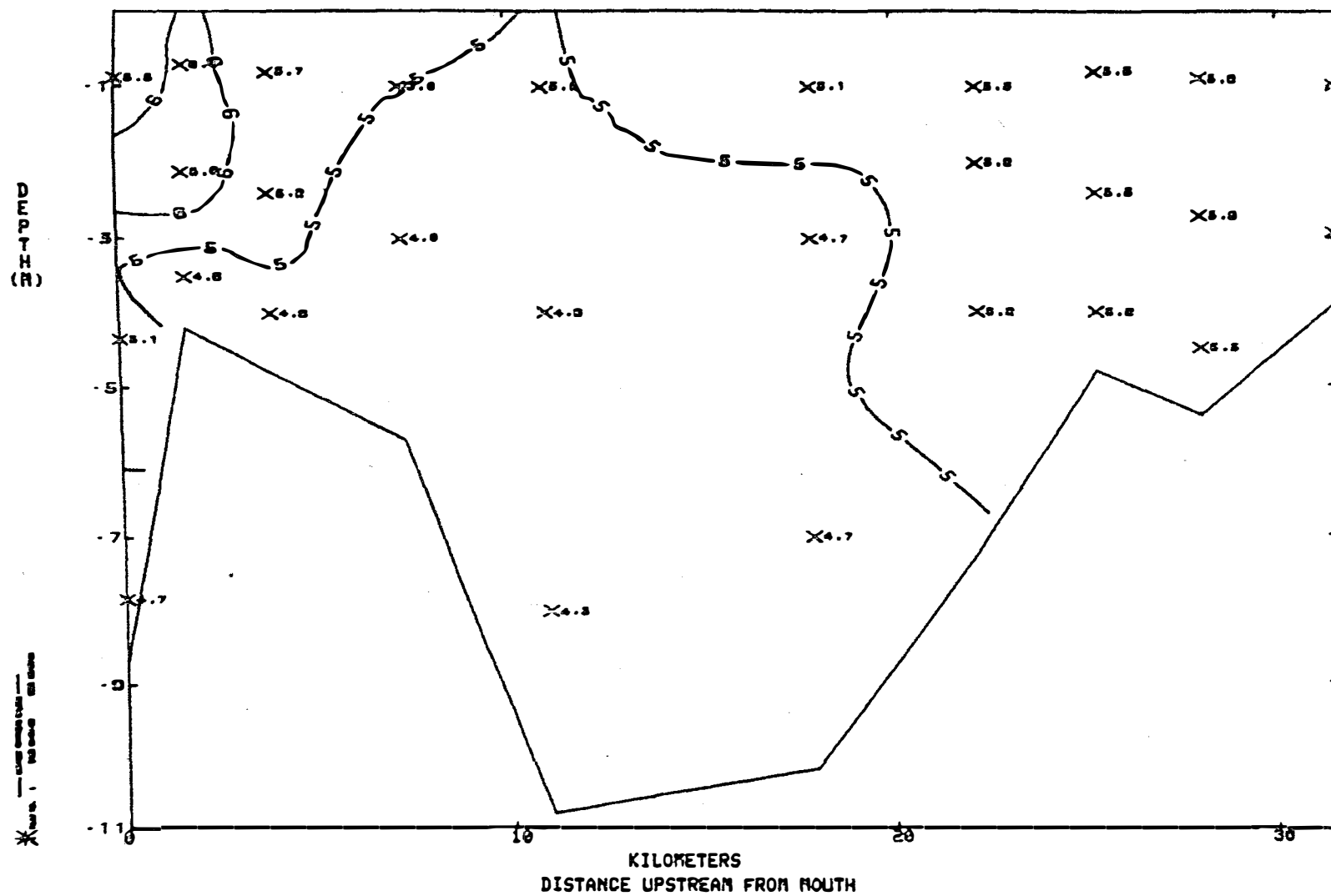


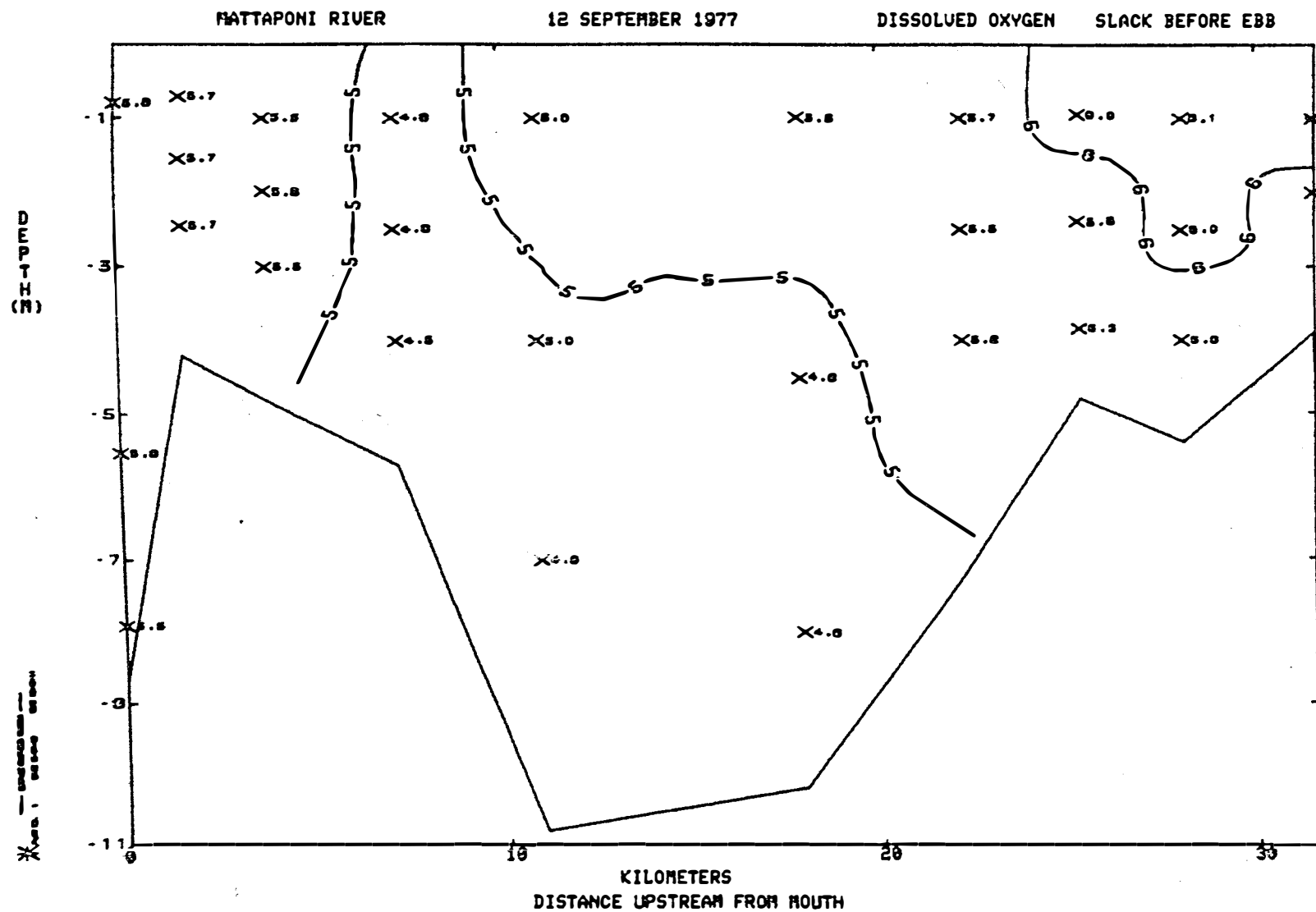






SLACK BEFORE FLOOD



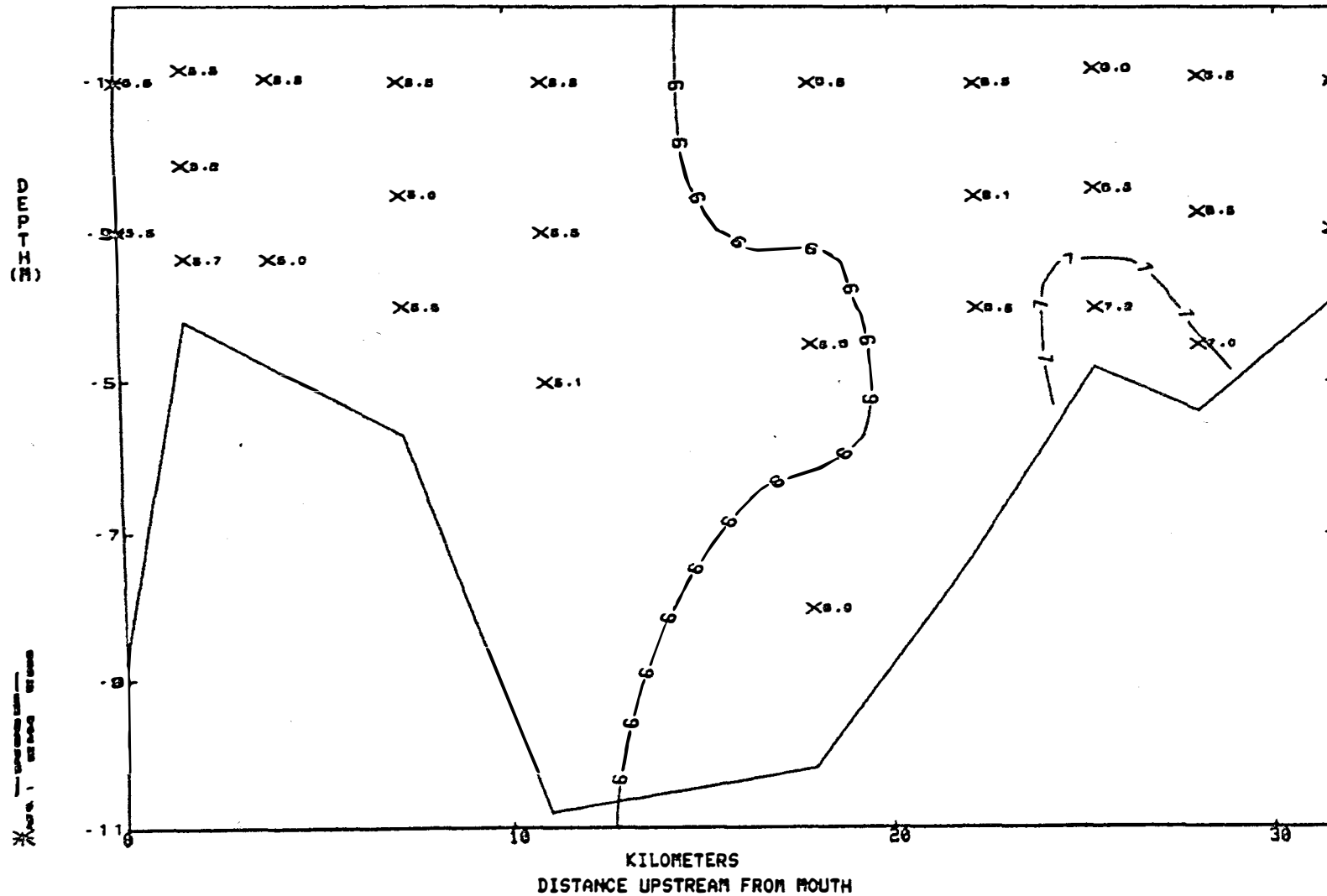


MATTAPONI RIVER

14 SEPTEMBER 1977

DISSOLVED OXYGEN

SLACK BEFORE FLOOD

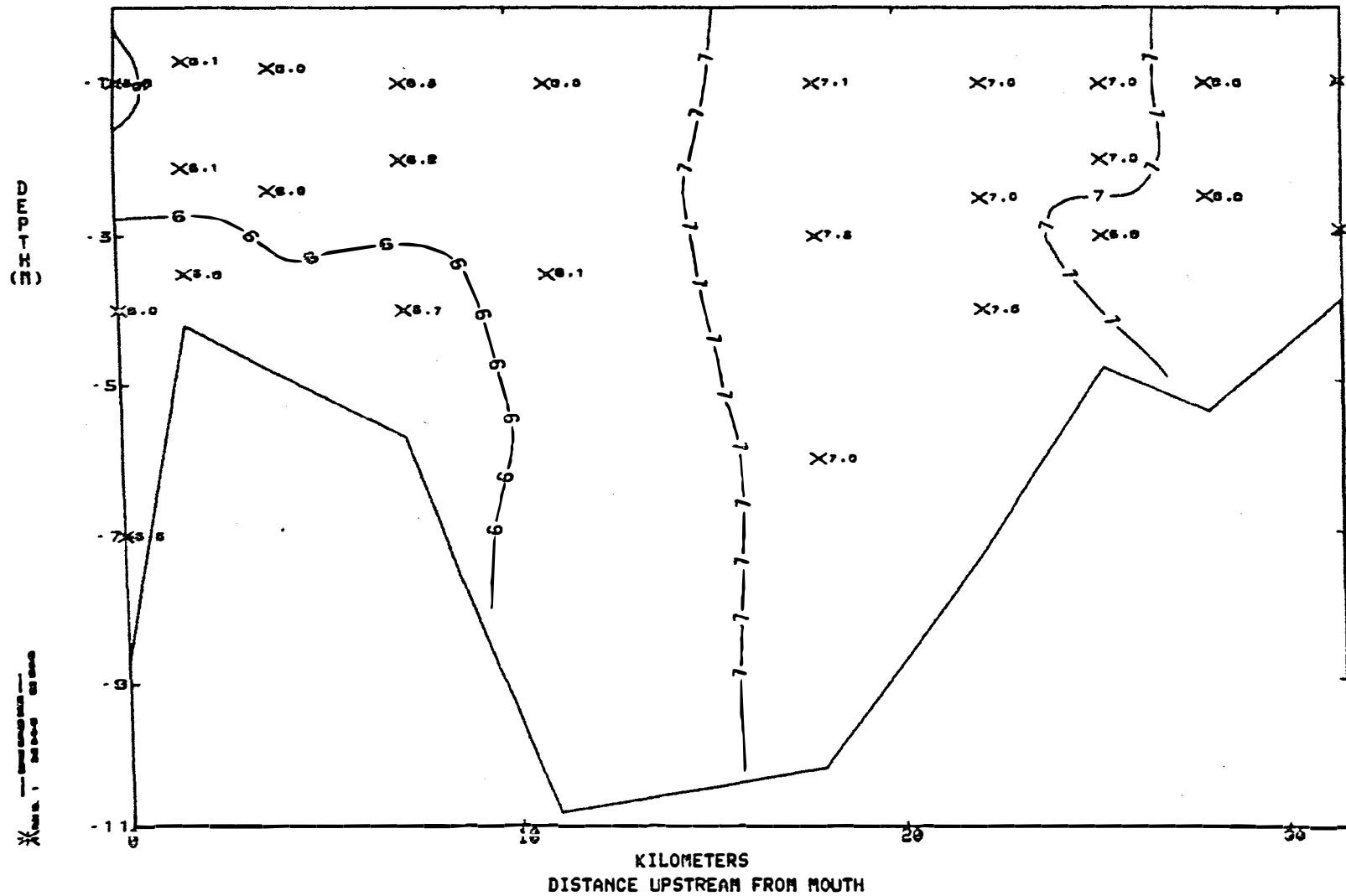


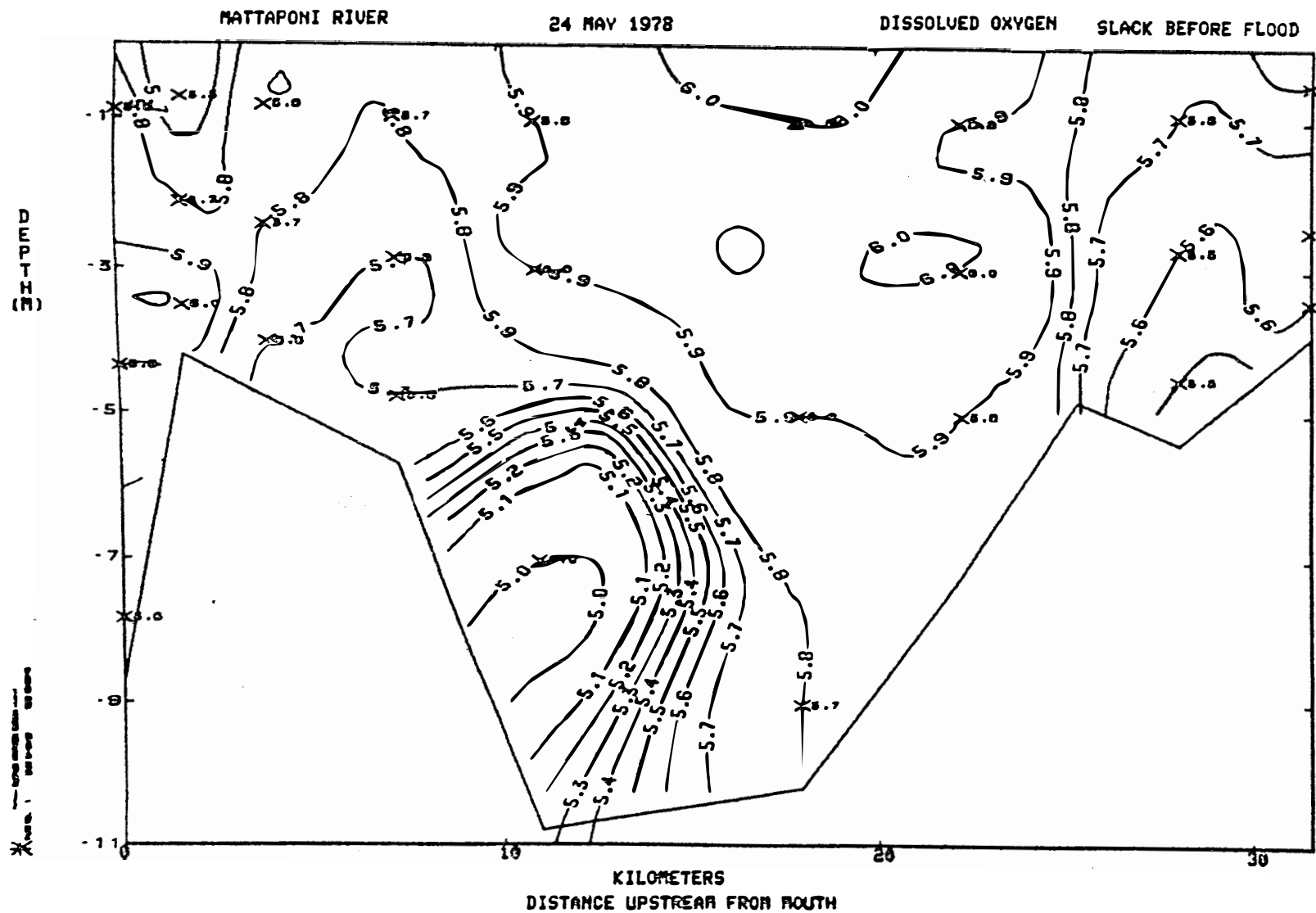
MATTAPONI RIVER

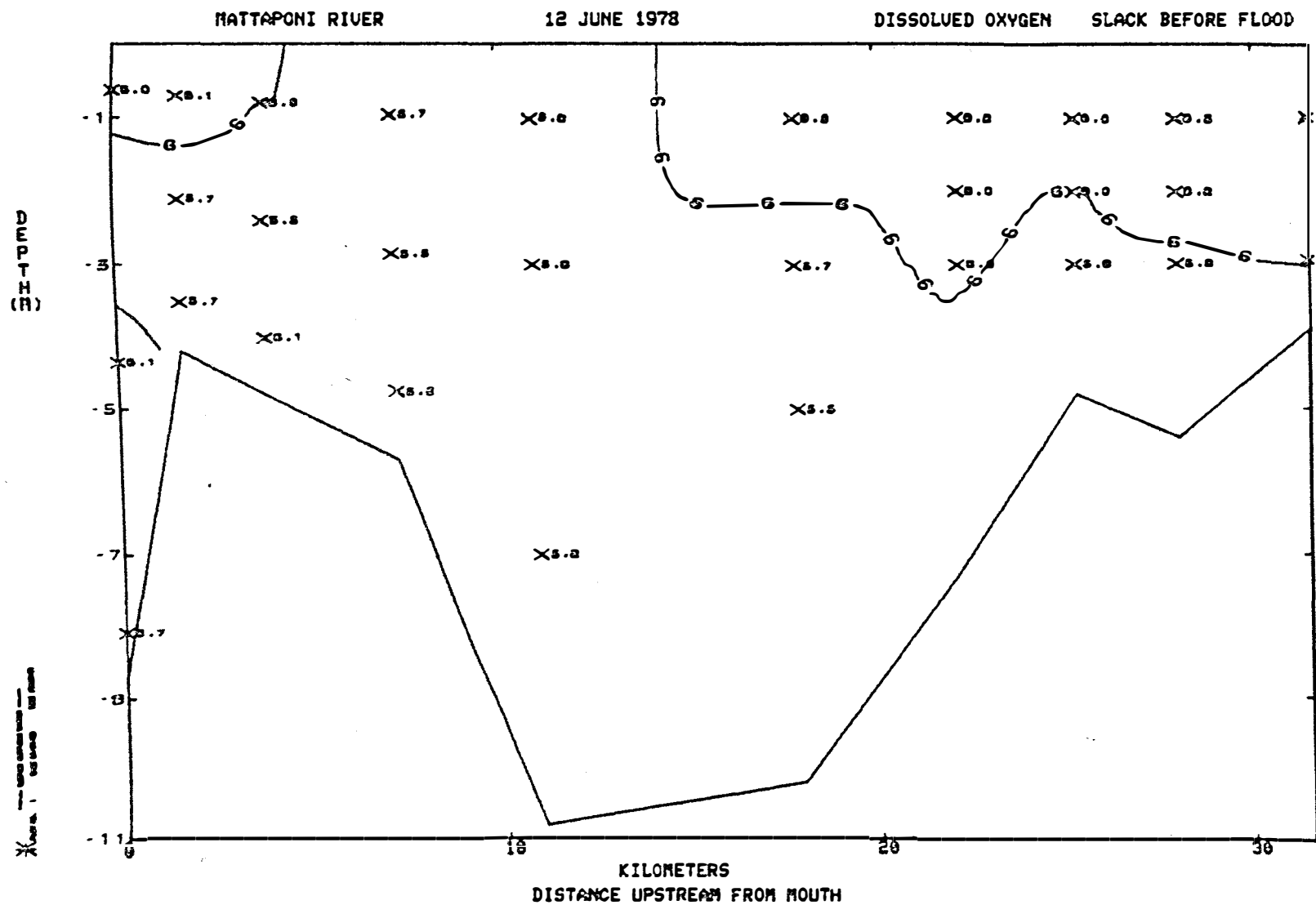
04 OCTOBER 1977

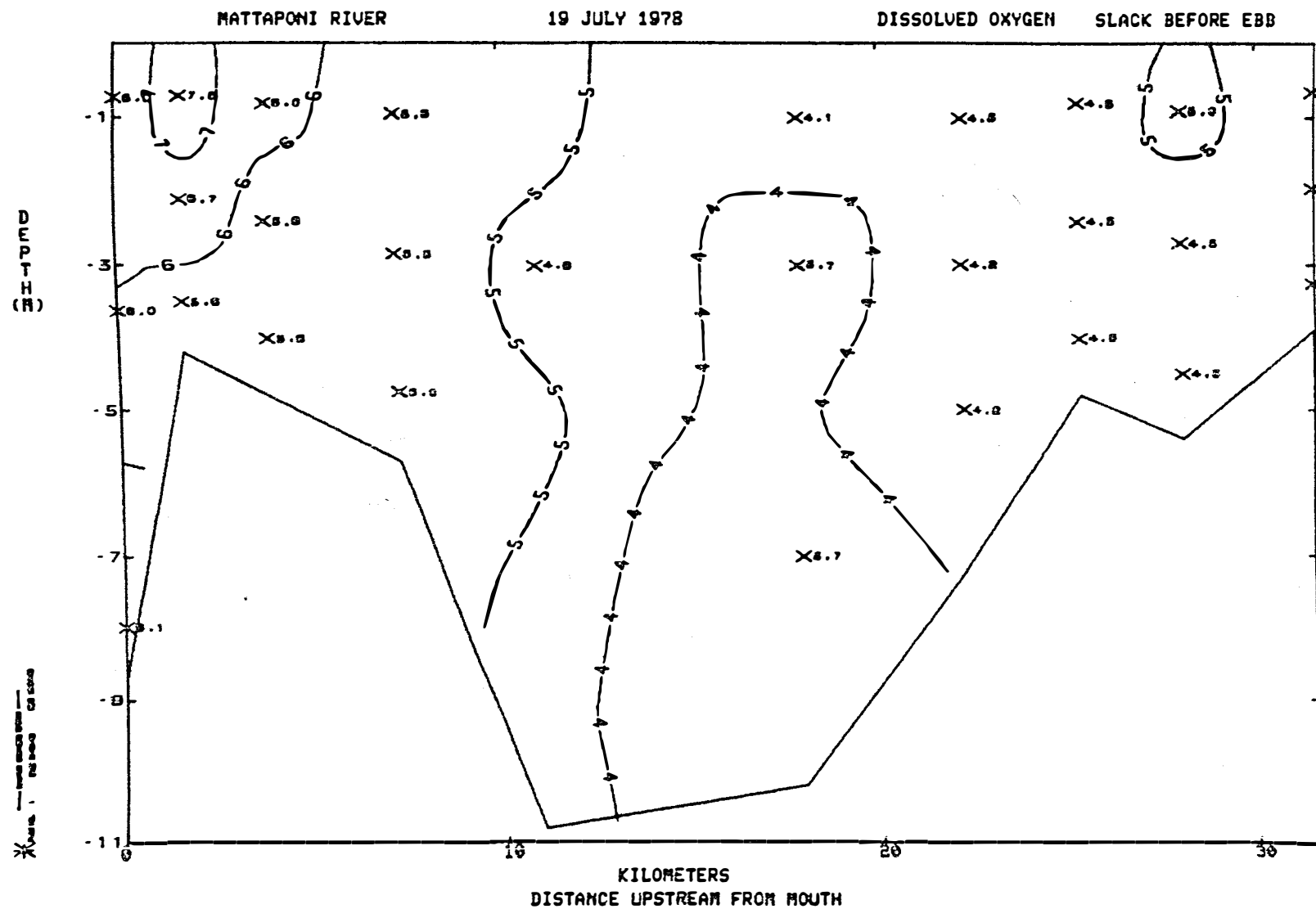
DISSOLVED OXYGEN

SLACK BEFORE FLOOD







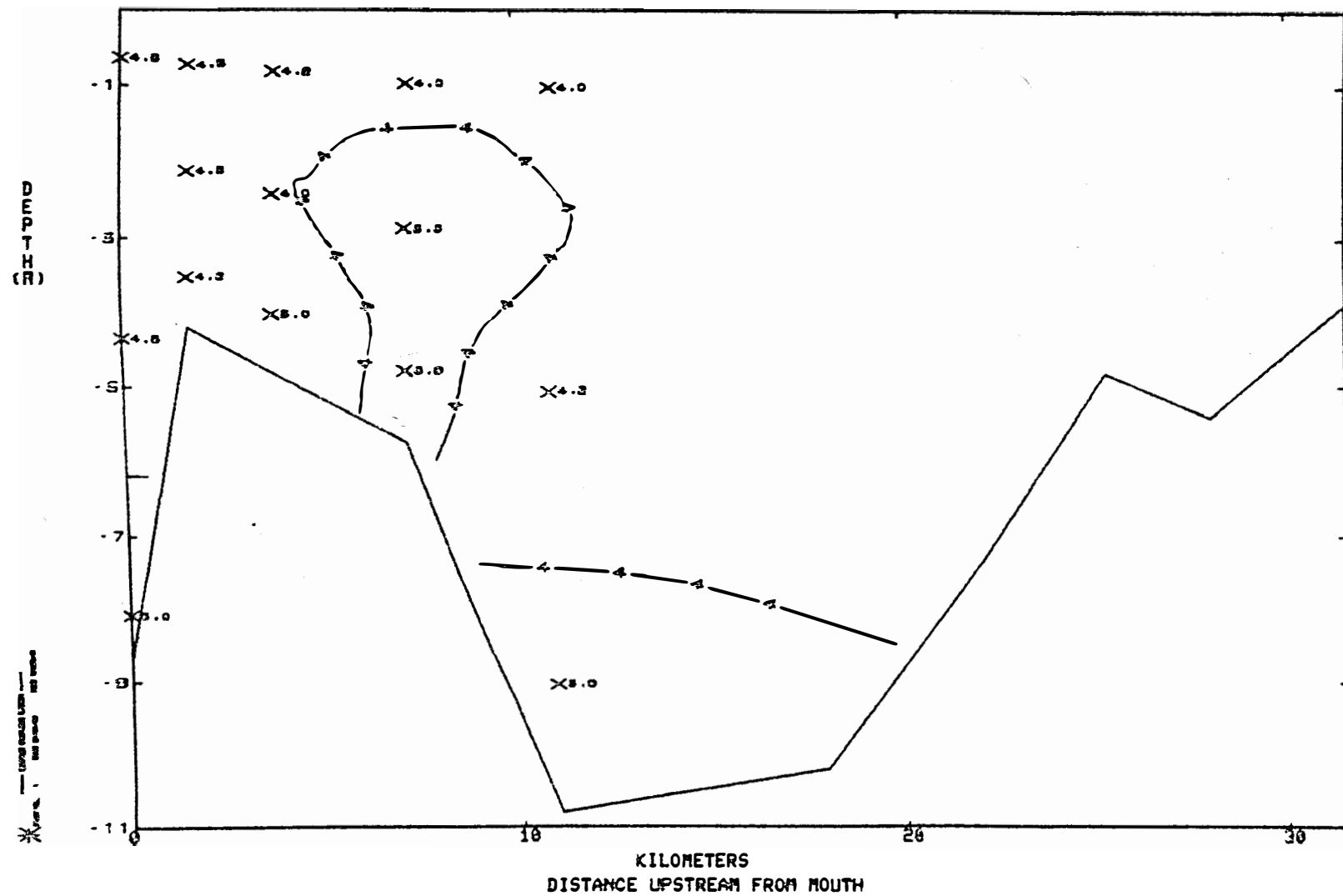


MATTAPONI RIVER

21 AUGUST 1978

DISSOLVED OXYGEN

SLACK BEFORE FLOOD

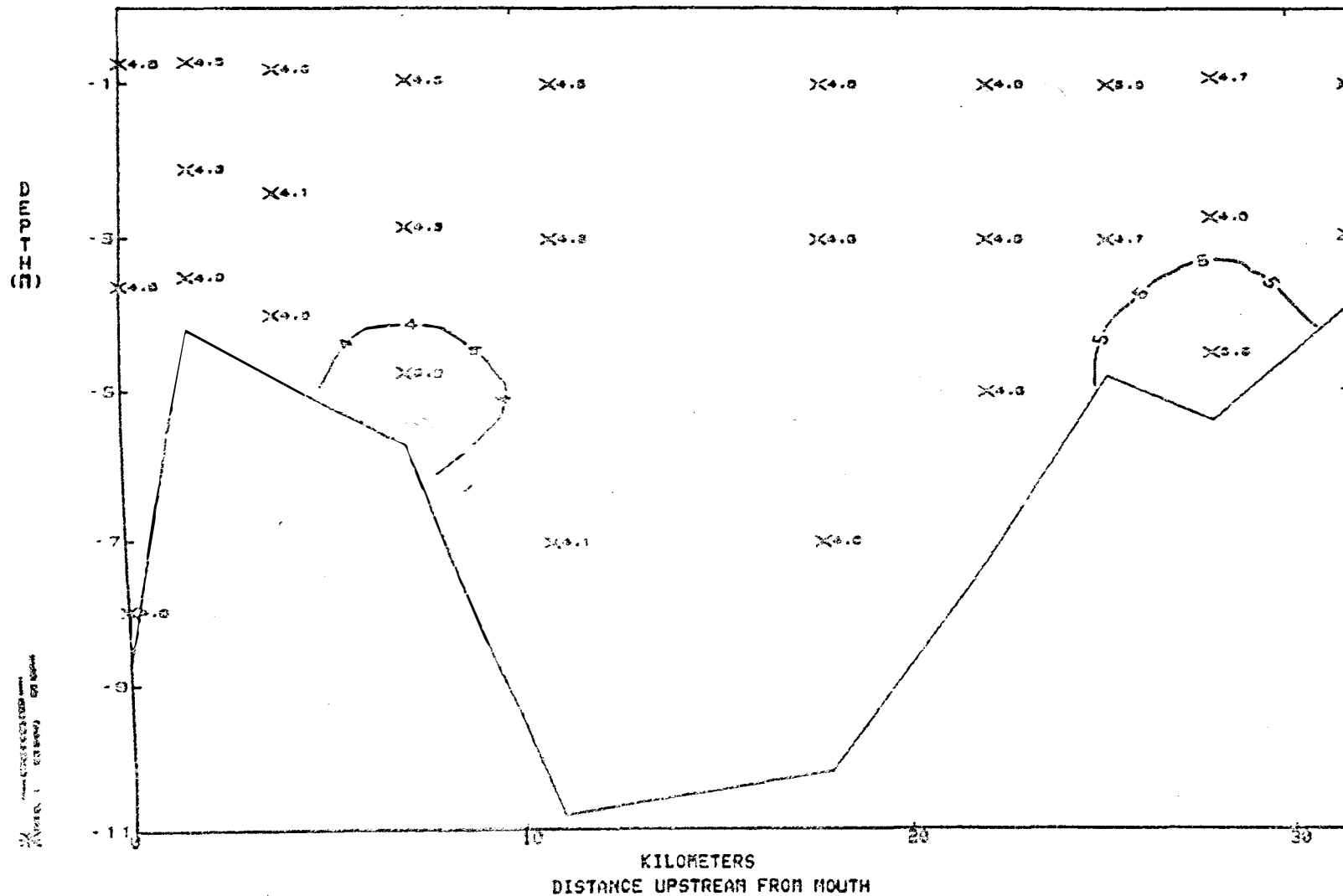


HATTAPONI RIVER

19 SEPTEMBER 1978

DISSOLVED OXYGEN

SLACK BEFORE FLOOD



MATTAPONI RIVER

11 OCTOBER 1978

DISSOLVED OXYGEN

SLACK BEFORE FLOOD

